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(54) Title: METHOD OF SCREENING FOR PROTEIN INHIBITORS AND ACTIVATORS

(57) Abstract

Inhibitors and activators of a protein whose expression affects a phenotypic characteristic of the cell, especially a cultural or morphological characteristic, are identified by their more pronounced effect on cells producing higher, usually non-naturally occurring, levels of the protein, than on cells producing little or none of the protein. In a preferred assay, the effect is observable with the naked eye. By this method, tamoxifen is identified as an inhibitor of PKC activity in cell culture.

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METHOD OF SCREENING FOR PROTEIN INHIBITORS AND
ACTIVATORS

BACKGROUND OF THE INVENTION

5 Field of the Invention

This invention relates to a general screening method for the discovery and identification of both inhibitors and activators of enzymes, receptors, and other proteins. In particular, it is concerned with 10 a method of screening for substances which specifically inhibit or activate a particular protein affecting the cultural or morphological characteristics of the cell expressing the protein, especially in a manner apparent to the naked eye.

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Information Disclosure Statement

A number of assay systems are currently in use for the discovery of new modulators of cell growth, and in 20 particular, in the search for new anti-cancer drugs which are specifically toxic to cancer cells but not to normal cells. A variety of changes may be scored for, but the most common ones are reversion of the transformed phenotype, significant changes in cell 25 morphology, or cytotoxicity. The assays include: (1) in vitro cytotoxicity assays; (2) soft agar colony formation assays; (3) in vitro anti-microbial assays; and (4) assays which detect changes in cellular morphology.

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In vitro cytotoxicity assays involve the measurement of cellular parameters which are indicative of inhibition of cellular growth or cytotoxicity. These include, for example, the measurement of the 35 inhibition of certain cellular metabolic pathways in

response to treatment with cytotoxic agents. The papers by Von Hoff, et al. (1985), and Catino, et al. (1985) describe typical methods which use this technique. These methods are somewhat complex 5 technically, and require the use of radioactive tracers in some cases. Furthermore, the results are non-specific since any agent which alters the growth properties of cells will score positively in these assay systems.

10

Agents have also been tested for their ability to inhibit transformed (cancerous) cells from growing in soft agar. This method is based upon the finding by Freedman and Shin (1974) that the formation of colonies 15 of cells in soft agar is the in vitro test which shows the highest correlation in predicting whether the cells will be tumorigenic in an experimental animal. This method is relatively simple to perform since colony growth will, after two or more weeks, generally be 20 large enough to be seen with the naked eye. Scoring the final results, therefore, can be performed either by a technician without extensive training in tissue culture, or, as we describe in the current application, by an automated absorbance detection system. In its 25 present form, however, this method is also non-specific for the same reasons as described above. In other words, any agent which inhibits cellular growth in any way will scores positively in this assay system as it is currently used, whether or not it inhibits the 30 protein of interest.

in vitro anti-microbial assays involve the use of bacterial or yeast strains which are used as test organisms for screening for agents with generalized 35 growth inhibitory properties (also described in Catino,

et al., 1985). In this method, the bacterial or yeast strain is grown on standard media plates and potential agents are applied to various spots on the plates. If an agent has growth inhibitory properties, a clear zone 5 results at the site of its application on the plate, resulting from the inability of the test strain to grow in the area. This method is rapid and can be performed by a technician without extensive training in tissue culture techniques, but the results are generally 10 non-specific because agents which are effective against bacterial or yeast strains are frequently less effective (or completely ineffective) in modulating the growth of mammalian cells, as shown in the paper by Catino et al. (1985).

15 Still other screening systems depend upon a morphologic alteration of the test cells by exposure to the potential agents in order to determine the effectiveness of a given agent. This method is 20 currently the most effective one for developing specific agents which interact with a given protein or alter a specific cellular property, as evidenced by the representative paper by Uehara, et. al. (1985). However, these screening systems are the most difficult 25 ones to apply in practice, since the morphologic effect of each individual agent on the test cells must be studied under the microscope. Hence this method requires extensive observations of the cells by a trained scientist.

30

SUMMARY OF THE INVENTION

The Method presented in detail in this application combines the rapidity and ease of performance of the 35 soft agar assay with a specificity for detecting an

active agent exceeding that of the morphology assay. In brief, the method which we describe herein involves the generation of a cell line purposefully engineered to detect both stimulatory and inhibitory agents which 5 are absolutely specific for any given protein which affects the cultural or morphological characteristics of the cell.

The basis for this invention is my observation 10 that if a protein (the "protein of interest", or POI) which is involved in some manner in cellular growth control is overproduced in cells, then pharmacologic agents which can activate or inhibit the POI can result in altered growth properties of the cells.

15

The sensitivity of the cells is dependent on their production of the POI, a phenomenon referred to herein as a "graded cellular response" to the pharmacologically active agent.

20

The present invention provides a rapid, yet powerful screening system for the discovery and identification of both inhibitors and activators of proteins. The method may be applied to virtually any 25 type of protein, including enzymes, receptors, DNA- or RNA-binding proteins, or others which are directly or indirectly involved in regulating cellular growth.

The method involves the insertion of a DNA (or 30 cDNA) sequence encoding the Protein Of Interest (POI) into an appropriate vector and the generation of cell lines which contain either (1) the expression vector alone ("control" cell lines) or (2) the expression vector containing the inserted DNA (or cDNA) sequence 35 encoding the POI ("test" cell lines). Using the

appropriate vector system, recipient cell lines, and growth conditions, test cell lines can thus be generated which stably overproduce the corresponding POI. Under the appropriate growth conditions, these 5 cell lines will exhibit a "graded cellular response" to activators or inhibitors of the POI. A screening system can thus be set up whereby the control and test cell lines are propagated in defined growth conditions in tissue culture dishes (or even in experimental 10 animals) and large numbers of compounds (or crude substances which may contain active compounds) can be screened for their effects on the POI.

Substances which inhibit or activate the POI may 15 affect characteristics such as growth rate, tumorigenic potential, anti-tumorigenic potential, anti-metastatic potential, cell morphology, antigen expression, and/or anchorage-independent growth capability. Substances which specifically inhibit or inactivate the POI may be 20 distinguished from substances which affect cell morphology or growth by other mechanisms in that they will have a greater effect on the test lines than on the control lines.

25 The system has been tested using several cDNA sequences and several recipient cell lines, and can be easily automated.

The appended claims are hereby incorporated by 30 reference as an enumeration of the preferred embodiments.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1A shows the full-length cDNA sequence, and the deduced amino acid sequence, of one of several forms of PKC which has previously been isolated (cDNA clone RP58), and whose partial sequence has been reported (Housey, et al., 1987). It corresponds to PKC_{beta} according to the nomenclature of Ono, et al. (1987). The deduced amino acid sequence begins with the first in-frame methionine codon at nucleotide position 91 and encodes a 671 amino acid protein with a predicted molecular weight of 76.8 kd. A consensus polyadenylation signal is underlined.

Figure 1B shows the retrovirus-derived cDNA expression vector, developed in this laboratory, which was used for the present studies. The full-length RP58 cDNA encoding PKC_{beta} (shown in 1A) was cloned into the Eco RI site of plasmid pMV7. The shaded region represents the coding sequence. "E" and "P" designate Eco RI and Pst I restriction sites, respectively. The indicated sizes between restriction sites in the RP58 cDNA are given in kilobases. "LTR" designates the 5' (left) and 3' (right) long terminal repeats of Moloney murine leukemia virus, and "TK-neo" designates the promoter region of the HSV thymidine kinase gene linked to the 5' end of the bacterial neomycin phosphotransferase (neo) gene.

Figure 1-C outlines in schematic form the overall strategy used to generate cell lines stably overproducing PKC.

Figure 2. Purification and Autophosphorylation of PKC. PKC activity from each cell line was purified and subjected to reaction conditions favoring autophosphorylation of PKC. Following the

autophosphorylation reaction, protein samples were separated by discontinuous polyacrylamide gel electrophoresis. In the lanes bearing odd numbers the reaction mixtures contained 1 mM Ca²⁺ and 5 phosphatidylserine to activate PKC, and in the lanes bearing even numbers the reaction mixtures contained 1 mM EGTA, 100 ng/ml TPA, and phosphatidylserine. The numbers in the left margin indicate the sizes of molecular weight markers, in kd. Arrows indicate the 10 position of the 75 kd autophosphorylated PKC.

Figure 3. Northern Blot Hybridization Analyses. Poly A+ RNA was isolated from the indicated cell lines and separated by electrophoresis on 6% formaldehyde/1% agarose gels, blotted onto nylon membrane and hybridized with the ³²P-labelled full-length RP58 cDNA probe, as previously described (Housey, et. al., 1987). The numbers in the right margin indicate the sizes in kb of the RNA markers. The R6-PKC4 sample displayed a 20 very weak 4.8 kb band on the original autoradiograph.

Figure 4. Morphologic Responses of the Cell Lines to Phorbol Ester Treatment. Nearly confluent cultures of the three indicated cell lines were exposed to 100 ng/ml TPA in 0.1 % dimethylsulfoxide (DMSO) solvent ("+TPA") or 0.1% DMSO alone ("-TPA"), in DMEM plus 10% CS. Photographs were taken 24 hours later (Panels A and D) and 48 hours later (Panels B and E). Fresh medium plus or minus TPA was then added and photographs 30 were then taken an additional 24 hours later (Panels C and F). (Magnification : 100X).

Figure 5. Growth Curves of Control and PKC-Overproducing Cell Lines. The indicated cell lines 35 were seeded at 1×10^4 per 6 cm plate in DMEM plus 10%

CS, in the presence ("+TPA") and absence ("−TPA") of 100 ng/ml TPA. Cell numbers were determined in replicate plates during the subsequent 11 day growth period. The values given indicate the means of 5 triplicate determinations, which varied by less than 10%.

Figure 6. Post-confluence Foci Formation. Control R6-C2 cells (Panel A) and R6-PKC3 cells (Panels B and 10 C) were grown to confluence and then maintained for an additional 28 days in DMEM plus 10% CS (without TPA), with the addition of fresh medium every 3 days. Photographs were taken at the end of the 28 day period. Magnification : 40 X.

15

Figure 7. Growth in Soft Agar. Cell lines R6-C1, R6-PKC3, and R6-PKC5 were seeded into 60 mm petri dishes in 0.3% agar containing DMEM plus 20% FBS and 50 µg/ml G418, plus or minus 100 ng/ml TPA. Photographs 20 were taken after 21 days of growth. A) R6-C1 + TPA (low-power field) B) R6-C1 + TPA (medium-power field) C) R6-PKC3 D) R6-PKC3 + TPA E) R6-PKC5 F) R6-PKC5 + TPA For additional details see Experimental Procedures. (Magnification : 100 X in panel B; 40 X in 25 all other panels).

DETAILED DESCRIPTION OF THE INVENTION

The present method is intended for use in identifying potential chemical inhibitors or activators 5 of enzymes, receptors, or any proteins which have effects upon cell phenotype. This method requires two cell lines, preferably alike except for their expression (production) of the protein of interest at different levels (and any further differences 10 necessitated by that difference in expression). Inhibitors or activators are identified by their greater effect on the phenotype of the higher producing cell line.

15 Any phenotypic characteristic of the cell which is affected by expression of the protein of interest, other, of course, than the level of the protein itself, may be assayed. The phenotypic characteristic is preferably a "cultural" or "morphological" 20 characteristic of the cell. For purposes of the appended claims, these terms are defined as follows:

Cultural characteristics include, but are not limited to the nutrients required for growth, the 25 nutrients which, though not required for growth, markedly promote growth, the physical conditions (temperature, pH, gaseous environment, osmotic state, and anchorage dependence or independence) of the culture which affect growth, and the substances which 30 inhibit growth or even kill the cells.

Morphological characteristics, but are not limited to include the size and shape of cells, their arrangements, cell differentiation, and subcellular 35 structures.

Where the protein of interest is implicated in tumorigenesis or related phenomena,, the characteristic observed is preferably one related to cellular growth 5 control, differentiation, de-differentiation, carcinogenic transformation, metastasis, tumorigenesis, or angiogenesis.

Phenotypic changes which are observable with the 10 naked eye are of special interest. Changes in the ability of the cells to grow in an anchorage-independent manner, to grow in soft agar, to form foci in cell culture, and to take up selected stains are particularly appropriate phenomena for observation and 15 comparison.

The higher producing cell line is preferably obtained by introducing a gene encoding the Protein of Interest (POI) into a host cell. The gene may be a one 20 isolated from the genome of an organism, a cDNA prepared from an mRNA transcript isolated from an organism, or a synthetic duplicate of a naturally occurring gene. It may also have a sequence which does not occur exactly in nature, but rather corresponds to 25 a mutation (single or multiple) of a naturally occurring sequence. No limitation is intended on the manner in which this mutated sequence is obtained. The gene is operably linked to a promoter of gene expression which is functional in the host, such that 30 the corresponding Protein Of Interest (POI) is stably "overproduced" in the recipient cells to differing degrees. The promoter may be constitutive or inducible. By "overproduced", I mean that the POI is expressed at higher levels in the genetically 35 manipulated cell line than in the original cell line.

This allows one to generate cell lines which contain (or secrete) from as little as a few fold to more than 100-fold elevated levels of the POI relative to the control cells.

5

Any method may be used to introduce the gene into the host cell, including transfection with a retroviral vector, direct transfection (e.g., mediated by calcium phosphate or DEAE-dextran), and electroporation.

10 Preferably, a retroviral vector is used.

The host cells should exhibit a readily observable phenotypic change as a result of enhanced production of the POI. Preferably, this response should be proportional to the level of production of the POI. Finally, the cells should not spontaneously manifest the desired phenotypic change. For example, 3T3 cells form foci spontaneously. Among the preferred cell lines are Rat-6 fibroblasts, C3H10T 1/2 fibroblasts, and HL60. (HL60 is a human cell line that differentiates in response to PKC activation.) 3T3 cells may be used, but with the reservation stated above.

25 Generally speaking, it is preferable to maximize the ratio of production by the "overproducing" cell line to production by the "native" line. This is facilitated by selecting a host cell line which produces little or no POI, and introducing multiple 30 gene copies and/or using high signal strength promoters.

The Rat 6 embryo fibroblast cell line is a variant of the rat embryo fibroblast cell line established by Freeman et. al., (1972) and isolated by Hsiao et al.,

1986. This cell line has an unusually flat morphology, even when maintained in culture at post-confluence for extended periods of time, displays anchorage dependent growth and, thus far, has not undergone spontaneous transformation. It was also ideal for these studies since it has a very low level of endogenous PKC activity and a low level of high affinity receptors for phorbol esters.

10 While my most preferred host cell line is the Rat-6 fibroblast cell line, I have tested this Method with other cell types, including the mouse NIH-3T3 cell line as well as the C3H 10T1/2 cell line. Tables 1(a) and (b) below show the representative specific activities of seven NIH-3T3 and six C3H-10T1/2 cell lines stably overproducing PKC. I have also recently performed the same experiments with the human HeLa cell line. In each case the resulting cell lines all exhibited growth properties qualitatively identical to those described for the PKC-expressing Rat-6 fibroblast cell lines. Therefore these results clearly demonstrate that many different types of cells can be employed in this method. The experimental procedures used to generate these cell lines were also identical to those used in connection with the Rat-6 cell line.

If a cell line otherwise suitable for use as a control cell line produces excessive POI, it is possible to inhibit this production by incorporation of a known inhibitor into the culture medium for both the control and test cell lines, thus achieving a more favorable ratio of production. Contrariwise, if the level of POI production by the test cell line is too low, a known activator may be incorporated into the culture media.

It is desirable, but not necessary, that a suspected inhibitor or activator be tested on both a control line and an overproducing line in parallel.

5

What we are looking for is a increase in the phenotypic change exhibited by the cell which becomes greater with increasing expression of the POI. We call this a "graded cellular response," and it is by this 10 specialized response that we distinguish inhibitors or activators of the POI from agents that act upon other cell metabolites to effect a phenotypic change.

Thus, in a preferred embodiment, the cell lines 15 are assayed for their relative levels of the POI, and their ability to grow in anchorage-independent systems (e.g., matrices such as soft agar or methocel), to form small "foci" (areas of dense groups of cells clustered together and growing on top of one another) in tissue 20 culture dishes, to take up selected stains, or to bind an appropriately labeled antibody or other receptor for a cell surface epitope. In addition to exhibiting these growth control abnormalities, such cell lines will also be sensitive in their growth properties to 25 chemical agents which are capable of binding to, or modifying the biological effects of, the POI.

The method is particularly unique in that it can be employed to search rapidly for EITHER activators OR 30 inhibitors of a given POI, depending upon the need. The term "activators," as used herein, includes both substances necessary for the POI to become active in the first place, and substance which merely accentuate its activity. The term "inhibitors" includes both 35 substance which reduce the activity of the POI and

these which nullify it altogether. When a POI has more than one possible activity. The inhibitor or activator may modulate any or all of its activities.

5 The use of this screening method to identify inhibitors or activators of enzymes is of special interest. In particular, I am interested in using it to identify inhibitors or activators of enzymes involved in tumorigenesis and related phenomena, for
10 example, protein kinase C, ornithine decarboxylase, cyclic AMP-dependent protein kinase, the protein kinase domains of the insulin and EGF receptors, and the enzyme products of various cellular onc genes such as the c-src (PP60^{src}) or c-ras (P20^{ras}) genes.

15 Protein kinase C (PKC) is a Ca²⁺- and phospholipid-dependent serine/threonine protein kinase of fundamental importance in cellular growth control. PKC is activated endogenously by a wide variety of
20 growth factors, hormones, and neurotransmitters, and has been shown to be a high affinity receptor for the phorbol ester tumor promoters as well as other agents which possess tumor promoting activity (for reviews see Nishizuka 1986; 1984; Ashendel, 1984). PKC has been
25 shown to phosphorylate several intracellular protein substrates, including the epidermal growth factor (EGF) receptor (Hunter et al., 1984), pp60src (Gould et al., 1985), the insulin receptor (Bollag et al., 1986), p21 ras (Jeng et al., 1987), and many others (Nishizuka,
30 1986). Several laboratories have recently isolated cDNA clones encoding distinct forms of PKC, thus demonstrating that PKC is encoded by a multigene family (Ono et al., 1986, Knopf et al., 1986, Parker et al., 1986; Coussens et al., 1986; Makowske et al., 1986;
35 Ohno et al., 1987; Housey et al., 1987). The multiple

forms of PKC exhibit considerable tissue specificity (Knopf, et. al., 1986; Brandt et al., 1987; Ohno, et al, 1987; Housey, et. al., 1987) which suggests that there may be subtle differences in the function(s) of each of the distinct forms. However, all of the cDNA clones which have been isolated thus far that encode distinct forms of PKC share at least 65% overall deduced homology at the amino acid level, and transient expression experiments with some of these cDNA clones have shown that they encode serine/threonine protein kinase activities which bind to, or are activated by, the phorbol ester tumor promoters (Knopf, et. al., 1986, Ono, et. al., 1987).

We used the PKC β 1 cDNA clone for the present studies for the following reasons. With the exception of the brain, where its expression is very high, PKC β 1 is expressed at very low levels in most tissues, and its expression is virtually undetectable in Rat 6 fibroblasts (see below). Thus, we reasoned that using this form would maximize the phenotypic differences observed between control cells and cells overexpressing the introduced form of PKC. The PKC β 1 form is also of particular interest because within the PKC gene family its deduced carboxy terminal domain displays the highest overall homology to the catalytic subunit of the cyclic AMP-dependent protein kinase (PKA) and the cyclic GMP-dependent protein kinase (PKG) (Housey et al., 1987). The latter observation suggests that PKA, PKG, and the β 1 form of PKC may share a common ancestral serine/threonine protein kinase progenitor, and that the additional PKC genes may have been derived through evolutionary divergence from the β 1 form.

Agents which interact with certain structural proteins, such as actin and myosin, are also of interest. Mutations in the genes expressing these proteins may be involved in tumorigenesis and 5 metastasization. Such interactions can lead to changes in cell phenotype which can be assayed by this method.

As is set forth in greater detail below, I have produced cell lines which overproduce protein kinase C (PKC). These cell lines, unlike the control cells, grow 10 in soft agar even in the absence of the tumor promoting phorbol ester 12-O-tetradecanoylphorbol-13-acetate (TPA). TPA has been shown to be a potent activator of PKC. When TPA is added to the growth medium the 15 PKC-overproducing cell lines grow even better and form considerably larger colonies in soft agar. Furthermore, I have also tested known inhibitors of PKC activity which, as predicted, caused the PKC-overproducing cells to grow less well (or not at 20 all) in soft agar. Thus, the direct utility of this method in identifying both activators or inhibitors of a gene product, in this case PKC, has been clearly demonstrated.

25 In additional studies with other genes, most notably the c-H-ras oncogene, the catalytic subunit of the cyclic AMP-dependent protein kinase, the c-myc oncogene, and certain cDNA clones encoding phorbol-ester inducible proteins, similar results have 30 been obtained. Thus it is also clear that the method can be generalized to a wide variety of genes encoding proteins which are involved in cellular growth control in numerous cell types.

First I tested the capability of pMV7-based expression vectors (pMV7 is my preferred transfer vector) to produce several different types of proteins in various cell lines. I used the cDNA sequences encoding the following proteins: hypoxanthine/guanine phosphoribosyltransferase (HGPRT), the human T4 lymphocyte cell surface antigen, the human T8 lymphocyte cell surface antigen, and ornithine decarboxylase (ODC). In each case the pMV7 vector was capable of producing high levels of expression of the relevant gene thereby resulting in overproduction of the corresponding protein product.

Once I had verified that the pMV7-derived expression vector could reproducibly generate cell lines which stably overproduced proteins I then tested additional genes which encode proteins, other than PKC, which are also involved in cellular growth control.

In the first case I chose a cDNA clone which, in collaboration with others, I had previously isolated and characterized. This cDNA clone, designated TPA-S1, encodes a protein of as yet unknown function. Thus I chose this clone for the express purpose of testing the method under conditions where a gene is used which encodes a protein of unknown function. Since we had previously demonstrated that the transcription of the TPA-S1 gene is rapidly and strongly induced following the treatment of cells with tumor promoters such as TPA (Johnson, et al., 1987), it appeared that the TPA-S1 gene product played some role in cellular growth control, but we had no additional data regarding its function. Thus, to further test the Method, the TPA-S1 cDNA was cloned into the pMV7 expression vector, resulting in a plasmid construct designated

pMV7-TPA-S1, and cell lines were generated which stably overexpressed the TPA-S1 cDNA clone. These cell lines were generated exactly as described for the R6-PKC α series cell lines described below.

5

In this case the results were also qualitatively identical since the NIH/3T3-tpa-s1 cell lines which were generated that stably overproduced the tpa-s1 encoded protein were also found to exhibit anchorage 10 independent growth in soft agar. This growth, furthermore, was dependent upon the level of TPA-S1 mRNA and TPA-S1 protein which was being synthesized in each cell line. Thus these cell lines could be used, in strictly analogous manner to the R6-PKC α series cell 15 lines, for the development of either an inhibitor or an activator of the TPA-S1 protein using the Method as described herein. It should be noted, in addition, that in these experiments we were able to obtain cell lines overproducing TPA-S1 which exhibited plating 20 efficiencies in soft agar in excess of 80%, even though the TPA-S1 gene does not appear to be an oncogene by the standard definition of the latter term.

In further experiments, I have tested the method 25 using an activated c-H-ras oncogene (T24), again in analogous fashion to the techniques described herein, and again with analogous results to those described herein for both the PKC cDNA clone and the TPA-S1 cDNA clone. Thus, the Method can also be used for the rapid 30 development of a p21 ras inhibitor. Taken together, the results described in this application demonstrate directly that the Method described herein is clearly generalizable to any gene which is involved in any way in cellular growth control.

35

The preferred protein inhibitor/activator drug screening method of the present invention comprises the following steps:

5 1. Construction of an expression vector which is capable of expressing the protein of interest in the selected host by inserting a gene encoding that protein into a transfer vector. The gene may be inserted 3' of a promoter already borne by the transfer vector, or a
10 gene and a promoter may be inserted sequentially or simultaneously.

15 2. Introduction of the expression vector (a) into cells which produce recombinant retrovirus particles, or (b) directly into host cells which will be used for subsequent drug screening tests (the resulting cells are called herein "test" cells).

20 In parallel, the transfer vector (i.e., the vector lacking the gene of interest and possibly a linked promoter but otherwise identical to the expression vector) is preferably also introduced into the host cells. Cell lines derived from this latter case will be used as negative controls in the
25 subsequent drug screening tests. Alternatively, the unmodified host cells may be used as controls.

30 If 2a was employed, after an appropriate time (usually 48 hours), media containing recombinant virus particles is transferred onto host cells so as to obtain test or control cells.

35 3. The test and control cells are transferred to selective growth medium containing the appropriate drug which will only allow those cells harboring the

expression vector containing the selectable marker gene (as well as the gene or cDNA of experimental interest) to grow. After an appropriate selection time (usually 7-10 days), individual clones of cells (derivative cell 5 lines) are isolated and propagated separately.

4. Each independent cell line is tested for the level of production of the POI. By this method, a range of cell lines is generated which overproduce from 10 a few fold to more than 100-fold levels of the POI. In parallel, the control cell lines which contain only the transfer vector alone (with the selectable marker gene) are also assayed for their endogenous levels of the POI.

15

5. Each independent line is then tested for its growth capability in soft agar (or methocel, or any other similar matrix) of various percentages and containing different types of growth media until cell 20 lines are identified which possess the desired growth characteristics as compared to the control cell lines.

6. Each cell line is also tested for its ability to form "foci", or areas of dense cellular growth, in 25 tissue culture plates using media containing various percentages and types of serum (20%, 10%, 5% serum, fetal calf serum, calf serum, horse serum, etc.) and under various conditions of growth (e.g. addition of 30 other hormones, growth factors, or other growth supplements to the medium, temperature and humidity variations, etc.). In these tests, the cells are maintained at post-confluence for extended periods of time (from two to eight weeks) with media changes every three days or as required. Such growth parameters are 35 varied until cell lines are identified which posess the

desired foci formation capacity relative to the control cell lines under the identical conditions.

7. After a cell line possessing the required growth characteristics is identified, the cells are grown under the conditions determined in (5) above with the growth medium supplemented with either crude or purified substances which may contain biologically active agents specific to the POI. Thus, crude or purified substances possessing the latter properties can be rapidly identified by their ability to differentially alter the growth properties of the experimental cells (which overproduce the POI) relative to the control cells (which do not). This can be done rapidly even by simple observation with the naked eye, since the colonies which grow in soft agar after 2 weeks are easily seen even without staining, although they may be stained for easier detection.

Similarly, if the post-confluence foci formation assay is chosen, the foci which result after approximately two weeks can be easily seen with the naked eye, or these foci can also be stained. For screening very large numbers of compounds (tens of thousands or more), the entire procedure can be performed on 96 well tissue culture plates. This applies equally well for either the soft agar growth assay or the tissue culture foci formation assay. Results of the assays can be rapidly determined by measuring the relative absorbance of the test cells as compared to the control cells (at 500 nm, or another appropriate wavelength). Absorbance readings may be rapidly performed in a 96-well plate absorbance reader such as the "Titer-tek" plate reader, or any of several analogous apparatus currently available. In this

fashion, thousands of compounds could be screened per month for their biological activity with very low labor and materials costs.

5 Furthermore, if antigen expression varies on teh test cells expressing high levels of the POI relative to the control cells, a simple Enzyme-Linked Immunoabsorption Assay (ELISA) could be performed and an antibody specific to the antigen.

10 While the assay may be performed with one control cell line and one test cell line, it is possible to use additional lines, tests lines with differing POI levels. Also additional sets of control/test lines, 15 originating from other hosts, may be tested.

Specific examples implementing the series of steps described above are as follows.

20 **Example 1**

If one were interested in screening for a protein kinase C (PKC) inhibitor, cell lines would be generated and selected which grow well in soft agar (as a result of their overproduction of any form of PKC) and yet show an enhancement of their growth when compounds which are known to stimulate PKC are added to the growth medium. Appropriate control cells, of course, would not exhibit any of these characteristics. Screening for a potent PKC inhibitor could then be performed by searching for those substances which could selectively inhibit the soft agar (anchorage-independent) growth of the PKC-overproducing cell lines. Alternatively, since the PKC-overproducing cells also form small, dense foci in tissue culture,

one could also screen for substances which inhibit this foci formation.

Described below are the detailed aspects of the relevant techniques and methods used to apply the principles of the invention to the problem of developing a system useful for screening for potent inhibitors of protein kinase C (PKC), a high-affinity intracellular receptor for tumor-promoting agents. The cell lines which resulted from the application of this method are highly sensitive and responsive both to agents which activate PKC as well as to those which inhibit PKC.

15 Construction of plasmid pMV7

The construction of pMV7 was begun with plasmid pPyori which contains the polyoma virus origin of replication cloned into the unique BamHI site of pML-1 (Lusky and Botchan, 1981). This plasmid replicates in murine cells that contain the polyoma T antigen (Dailey and Basilico, 1985). Plasmid pMV (Perkins et al., 1983) was then cleaved with HincII and BglI. The 2.29 kb fragment that contains the Moloney Leukemia Virus Long Terminal Repeats (LTR), the packaging site, the splice donor site, and the proline tRNA binding site was isolated.

During the original construction of pMV (Perkins et al., 1983) 3.95 kb was removed from the MSV genome by cleaving with PstI. This left a PstI site situated 380 bps 3' from the tRNA binding site and 308 bps from the 5' end of the 3' LTR (Reddy et al., 1981). Xho I linkers were added to the HincII-BglI fragment, and to pPyori after it had been cleaved with EcoRI and HindIII. The two fragments were ligated, after

activation of the linkers, and a plasmid, designated pMV-3, that contained the Moloney Virus control elements was isolated.

5 The unique EcoRI site was removed from this vector by digesting the plasmid with EcoRI and treating the linear molecules with T4 polymerase. These molecules were recircularized and a plasmid, pMV-4, lacking the EcoRI site, was isolated. An EcoRI linker was inserted
10 into this plasmid at the PstI site between the Moloney LTRs; the resultant plasmid was designated pMV-5.

The dominant selectable marker (neo) was added to pMV-5. The first step was isolating a 1.9 kb
15 BamHI-SalI fragment from pIPB1. This fragment contains the Herpes Simplex virus thymidine kinase (tk) promoter region and the coding sequence for the bacterial neo gene (neomycin phosphotransferase). This fragment was blunt-ended with T4 polymerase, ClaI linkers were added
20 and the fragment was cloned into the Cla I site 165 bps 3' to the EcoRI site in pMV-5, between the LTRs. This plasmid was designated pMV5-tk neo. The tk promoter has an EcoRI site 70 bps 5' to the start of transcription. This EcoRI site was removed by
25 partially digesting pMV5-tkneo with EcoRI, isolating the linear full length cut species, filling in the ends with T4 polymerase and recircularizing the molecule. A plasmid was chosen in which the EcoRI site previously present in the tk promoter sequence was removed, but
30 the EcoRI site 537 bps 3' to the start of transcription of the 5' LTR was retained. This plasmid was designated pMV7 and a map of this plasmid is shown in Figure 1B.

This vector consists of the 5' and 3' Moloney Murine Leukemia Virus (MoMuLV) LTRs, the MoMuLV RNA packaging site 3' to the 5' LTR, an Eco RI cloning site, a modified Herpes Simplex Virus thymidine kinase (tk) promoter (lacking an Eco RI site at -79 bp), and the selectable marker gene neo. cDNA clones inserted into the EcoRI cloning site are under the transcriptional control of the 5' LTR, whereas the neo gene is independently transcribed by the tk promoter. This structure favors maintenance of the functional integrity of the selectable marker without interfering with the expression of the 5' (unselected) cDNA sequence. It is known (Maddon et al., 1986; Daley et al., 1987) that when various cDNA sequences are inserted into the EcoR1 site of pMV7 they can be readily transferred into recipient cells by virus-mediated passage, are stably expressed, and yield high-level production of the corresponding protein.

20 Nucleotide Sequencing and Expression Vector Construction

Nucleotide sequencing of the PKC cDNA clone RP58, a full-length clone isolated from a rat brain 25 cDNA library, which corresponds to the previously reported clone RP41, was performed as previously described (Housey et al., 1987). The full-length cDNA sequence of RP58, which encodes PKC β 1 (Figure 1A), was subcloned into the EcoRI site of plasmid pMV7 using 30 standard methodology (Maniatis et al., 1983). The general structure of pMV7 is shown in Figure 1B. The construct resulting from insertion of the PKC β 1 gene is designated pMV7-PKC β 1.

35 Isolation of cell lines stably overexpressing PKC

20 ug of CsCl banded pMV7 or pMV7-PKC β 1 plasmid DNA were transfected (Graham and van der Eb, 1973; as modified by Wigler et al., 1977) onto 5 subconfluent "Psi-2" cells (Mann et al., 1985). After 48 hrs the culture medium was collected, filtered through a 0.45 um filter and stored at -70°C. Recipient subconfluent Rat-6 fibroblasts (5×10^5 per 10 cm plate) were infected with the virus-containing medium 10 in 2 ug/ml polybrene for 48 hrs. The cells, grown to confluence, were then trypsinized and replated in Dulbecco's-modified Eagle's medium (DMEM) supplemented with 10% bovine calf serum (CS) (Flow Laboratories) with 200 ug/ml of the neomycin derivative G418 15 (Geneticin). Resistant colonies were cloned by ring isolation after 1 week of G418 selection.

After approximately ten days of growth in selective medium, ten individual G418-resistant clones 20 were isolated and maintained independently in G418-containing medium. These lines were designated R6-PKC β 1 through R6-PKC β 110 (abbreviated as R6-PKC1 through R6-PKC10). In parallel, a set of control Rat 6 lines was generated by transfection of 25 the plasmid pMV7 (lacking the PKC cDNA insert) onto W-2 cells, infection of recipient Rat-6 cells, and selection for G418 resistance as described above for plasmid pMV7-PKC β 1. Similarly, after ten days of growth in the G418-containing medium, five individual, 30 well-isolated G418-resistant clones were then isolated and maintained independently. These control lines were designated R6-C1 through R6-C5.

RNA Isolation and Blot Hybridization Analyses

Poly A+ RNA isolations, gel electrophoresis, and blot hybridization analyses were performed as previously described (Housey, et. al., 1985). RNA molecular weight markers were obtained from Bethesda Research Laboratories. The 2.7kb cDNA insert of RP58 (see above) was subcloned into plasmid pKS(+) (Stratagene Cloning Systems) to yield a plasmid designated ps2-RP58. A ³²P-labelled probe was prepared from ps2-RP58 and used under high-stringency hybridization conditions as previously described (Housey et al., 1987).

Purification and Assay of PKC Activity From Tissue Culture Cells

15

The total PKC activity (membrane-associated plus cytosolic) present in cultured cells was determined after partial purification of cellular extracts as follows.

20

Three 10 cm plates of confluent cells were washed twice with 10 ml of ice-cold phosphate-buffered saline (PBS) and then 10 ml of homogenization buffer (20 mM Tris, pH 7.5, 5 mM EGTA, 5mM EDTA, 15 mM 2-mercaptoethanol, 10 ug/ml soybean trypsin inhibitor, 10 ug/ml leupeptin, 40 ug/ml phenylmethylsulfonyl fluoride), containing 0.1% Triton X-100 were added. The cells were then scraped from each of the plates, pooled and disrupted with 25 strokes in a Dounce homogenizer. The homogenate was transferred to a 15 ml disposable polystyrene tube, centrifuged at 2000 x g for 5 minutes at 4°C, and the supernatant was loaded onto a 1 ml DEAE Sephadex column previously equilibrated with 10 ml homogenization buffer, at 4°C. The column was washed with 10 ml homogenization buffer

and then the bound enzyme was eluted with 3 ml of homogenization buffer containing 0.5 M NaCl. Total protein concentrations were determined by the method of Bradford (1976).

5

The PKC activity present in the above-described partially purified cell extracts above was assayed immediately after isolation. The synthetic peptide R-K-R-T-L-R-R-L, corresponding to amino acids 651-658 of the epidermal growth factor receptor (Ullrich et al., 1984), was synthesized on an Applied Biosystems model 430A peptide synthesizer, purified by high-performance liquid chromatography, lyophilized, and stored at -20 oC. The Threonine at position 654 is an in vivo substrate for PKC (Hunter, et al., 1984; Davis and Czech, 1985). This synthetic peptide is a highly specific substrate for PKC activity in vitro. (Watson et al., 1987; Woodgett, et al., 1986).

20

The purified material was then redissolved in sterile water at a final concentration of 100 uM and used as the phosphoacceptor substrate in the PKC assays. The general method of assay has been published in detail elsewhere (O'Brian et al., 1985). In most cases, 100 uM synthetic peptide was substituted for 2 mg/ml histone III-S as the phosphoacceptor substrate.

30

Cell extracts were prepared 48 hours after the cells had reached confluence. As shown in Table 1(a), eight of the ten cell lines generated by infection with the pMV7-PKC β 1 construct (lines R6-PKC1, R6-PKC3, and R6-PKC5 through R6-PKC10) contained marked increases in PKC activity when compared to the control lines (R6-C1, -C2, and -C3). It is remarkable that cell line R6-PKC3 contained a 53 fold higher level of

PKC activity than that present in the control cells. Two of the lines (R6-PKC2 and R6-PKC4), however, did not display a significant increase in PKC activity, yet they presumably had integrated the pMV7-PKC construct 5 as evidenced by their continued G418 resistance. Subsequent studies verified that these two cell lines contained deletions in the cDNA clone encoding PKC_{beta}1.

10 In additional studies I found that the very high PKC activity in extracts of R6-PKC3 seen in the presence of 1mM Ca²⁺ and phosphatidylserine was also apparent in the presence of 1mM EGTA, 100 ng/ml TPA and phosphatidylserine. This very high activity was also 15 seen when we employed histone III-S, rather than the above-described synthetic peptide, as the substrate for phosphorylation. Furthermore, even after 24 weeks of continuous growth and serial passage, the cell lines R6-PKC1 through R6-PKC6 displayed essentially the same 20 levels of PKC activity shown in Table 1.

Autophosphorylation and Gel Electrophoresis of PKC

25 Cell extracts purified as described above were incubated under conditions which favor the autophosphorylation of PKC, as follows. One hundred ug of partially purified protein extract was incubated in a reaction mixture containing 80 ug/ml phosphatidylserine, 1 mM CaCl₂ (or 1 mM EGTA and 100 ng/ml TPA), 5 mM MgCl₂, and 30 uM ATP containing 100 uCi [γ -³²P]ATP (New England Nuclear, NEG035). The purity of the radioactive ATP is critical to obtain reproducible autophosphorylation of PKC.

Under these conditions, it has been previously shown that PKC undergoes an autophosphorylation reaction which results in the phosphorylation of several sites on the intact enzyme (Walton et al., 5 1987; Huang et al., 1986, Woodgett and Hunter, 1986; Kikkawa, 1982).

Reactions were incubated at room temperature for 10 minutes and then stopped by the addition of SDS-PAGE 10 loading buffer containing 2-mercaptoethanol. This material was then subjected to discontinuous SDS-PAGE by a modification of the method of Laemmli (1970). Twenty ug of total protein were loaded onto each lane. Following electrophoresis, the gels were fixed in 50% 15 acetic acid, 10% ethanol, dried, and autoradiographed on Kodak XAR-5 film.

Autoradiographs of these gels (Figure 2) revealed that the extracts prepared from four cell lines that 20 had high PKC activity (R6-PKC1, -PKC3, -PKC5, and -PKC6, see Table 1(a)) displayed a prominent phosphorylated protein band which was about 75 kd in size, corresponding to the size of an autophosphorylated preparation of PKC obtained from rat 25 brain (Huang et al., 1986; Housey et al., 1987). When examined in an immunoblot assay this 75 kd band also reacted with an antibody to the betal form of PKC (Jaken and Kiley, 1987). The control cell lines R6-C1, -C2 and -C3, and the cell lines R6-PKC2 and R6-PKC4, 30 which did not have increased levels of PKC (see Table 1(a)) did not show this 75 kd phosphorylated band (Figure 2), nor did they contain any bands which reacted with the antibody to the betal form of PKC. It 35 is of interest that the samples obtained from the four cell lines that produced high levels of PKC also

displayed weaker but distinct phosphorylated protein bands that were about 73, 60, and 49 kd in size, which were not seen (or only faintly detected) in the extracts from cells that did not have increased levels 5 of PKC (Figure 2). These bands may represent degradation fragments of the 75 kd PKC molecules, or specific cellular proteins that are phosphorylated by PKC.

10 The above-described phosphorylated protein bands were seen when either 1 mM Ca²⁺ plus phosphatidylserine or 100 ng/ml TPA plus phosphatidylserine were used as cofactors for PKC activation (compare even and odd numbered lanes in Figure 2). When, however, extracts 15 from cell lines producing high levels of PKC were incubated in an autophosphorylation reaction in the absence of such cofactors, the 75 kd band and the additional smaller bands described above were not detected. These results, taken together with the 20 negative results obtained with extracts from the control cells (Figure 2), clearly indicate that the phosphorylated bands reflect PKC activity.

Phorbol Ester (³H-PDBU) Binding Assays

25 Since it has been shown that PKC is a high affinity intracellular receptor for the phorbol ester tumor promoters (for review, see Nishizuka, 1986), I also assayed a subset of the cell lines for ³H-PDBu 30 binding using a previously described intact cell assay (Horowitz et al., 1981).

Cells were plated at 1×10^5 per 4 cm well on day 1, the medium was changed on day 2 and the cells then 35 assayed on day 3. The monolayer was washed with 4 ml of

DMEM (without serum), then 2 ml of DMEM containing 50 nM ^3H -PDBU (New England Nuclear; 8.3 Ci/mmol) was added and the plates were incubated for 1 hr at 37°C to determine total binding. The fraction of the total binding that represented specific binding was determined by the addition of a 1000-fold excess of unlabelled PDBU (LC Services) to the ^3H -PDBU stock (Horowitz et al., 1981). The plates were washed 3x with 4 ml ice-cold PBS. The cells were solubilized in 1 ml 1% SDS/10 mM DTT for 2 hrs at 37°C. The lysate was transferred to a scintillation vial and counted. Replica plates were used to determine the number of cells per plate and the specific binding data expressed as nanomoles ^3H -PDBu bound/ 10^6 cells. Scatchard analyses were performed as previously described (Horowitz et al., 1981).

I found that the R6-PKC cell lines 1,3,5 and 6, all of which had high PKC enzyme activity, also had a marked increase in ^3H -PDBu binding, whereas the cell line R6-PKC4, which did not display a significant increase in PKC activity, did not show an increase in ^3H -PDBu binding when compared to the two control cell lines R6-C1 and R6-C2 (Table 1(a)). Scatchard analyses of the control cell line R6-C1 and of the R6-PKC3 cell line, performed as previously described (Horowitz et al., 1981), indicated that the number of high affinity receptors in the two cell lines was 1.6×10^5 and 1.4×10^6 , respectively. The affinity constants were approximately the same in both cell lines ($K_d = 16$ nM). Thus, under the assay conditions used, the R6-PKC3 cells contain about ten times the level of high affinity phorbol-ester binding sites as the control cells. It is apparent that the cell lines that express

very high levels of PKC also have a significant increase in phorbol ester binding sites.

Assays for PKC-related RNA transcripts

5

In view of the above results, it was of interest to analyze the poly A+ RNA fraction of several of the cell lines described in Table 1(a) for the size and abundance of RNA transcripts containing sequences 10 homologous to PKC β 1.

Poly A+ RNA was separated on 1% agarose, 6%-formaldehyde gels, blotted onto nylon membranes, hybridized to a 32P-labelled DNA probe prepared from 15 the full-length PKC β 1 cDNA, and autoradiographed, as previously described (Housey, et al., 1986). As shown in Figure 3, the lines that contained elevated levels of PKC activity (R6-PKC1,-PKC3,-PKC5, and -PKC6, see Table 1(a)) contained a prominent 6.6 kb RNA species 20 which corresponds to the predicted size for a mRNA transcript that initiates in the 5' LTR and terminates in the 3' LTR of the pMV7-PKC β 1 construct. This transcript was most abundant in the R6-PKC3 cell line 25 (Figure 3) which also expresses the highest level of PKC activity (Table 1).

On the other hand, lines R6-PKC2 and R6-PKC4, which showed no significant elevation of PKC activity (Table 1(a)), produced truncated mRNA's of approximately 5 kb and 4.8 kb, respectively. The 30 abundance of the latter transcripts was much lower than that of the 6.6 kb transcripts present in the cell lines that expressed high levels of PKC. The neot phenotype and the lack of PKC activity in cell lines R6-PKC2 and R6-PKC4 suggest that the truncated mRNAs 35 reflect deletions in PKC coding sequences in the

integrated constructs carried by these cell lines. Indeed, genomic DNA blot hybridizations of clones R6-PKC2 and R6-PKC4 indicated that they contained deletions in the PKC β 1 cDNA sequence. Neither in the parental Rat 6 cell line, nor in any of the experimental cell lines derived from these cells, was it possible to detect evidence of an endogenous transcript homologous to the PKC β 1 probe (Figure 3). Thus, in these cells, there is negligible expression of the endogenous gene encoding PKC β 1.

Assays of Growth in Monolayer Culture and in Soft Agar

Cells were seeded at a density of 10^4 /plate in a series of 60 mm plates, in 5 ml DMEM plus 10% CS. Twenty-four hours later, cells in triplicate plates were trypsinized and counted. This point was designated "day 0." The remaining cultures were then grown in the respective medium (i.e. plus or minus 100 ng/ml TPA) with fresh medium changes twice per week. Cell counts per plate were then determined on triplicate plates during the remainder of the growth curve (Figure 3). The results obtained were analyzed for exponential doubling time and saturation density (Table 2). To assess growth in soft agar (anchorage independence), 2×10^4 cells were suspended in 2 ml of 0.3% Bacto agar (Difco Laboratories, Detroit, MI) in DMEM containing 20% fetal calf serum (FCS) and overlayed above a layer of 5 ml of 0.5% agar in the same medium, on 60 mm petri dishes. The cells were then overlaid with DMEM plus 20% FCS every 4 days. At the end of 30 days, colonies were stained with the vital stain 2-(p-iodophenyl)-3-(p-nitrophenyl)-5-phenyltetrazolium chloride hydrate (INT) (Sigma Chemical Co., St. Louis, MO) for 48 hours at 37 oC, in an incubator with

5% CO₂ (Schaeffer and Friend, 1976), and the number of colonies counted under low power on an inverted phase microscope. The data are expressed as "cloning efficiency", i.e. number of colonies greater than 0.05 mm per plate X 100 divided by the number of cells originally seeded per plate.

Screening of a Known Activator of PKC

10 We found that cell lines which overproduce PKC display an exaggerated morphologic response to 12-O-tetradecanoyl phorbol-13-acetate (TPA) and altered growth control.

15 Changes in Morphology

To further characterize the phenotypic changes which occurred in the cell lines that overproduce PKC_{beta}1, lines R6-PKC3 and R6-PKC5, which contain 53-
20 and 20-fold elevations of PKC activity, respectively,
were first examined in detail with respect to their
morphology, in comparison to the control cell line
R6-C1. As shown in Figure 4, Panel A, in the absence of
TPA treatment all three cell lines showed the
25 characteristic fusiform morphology of monolayer
cultures of the normal parental Rat 6 fibroblast cell
line. At 24 hours after treatment with 100 ng/ml TPA
(Figure 4, R6-C1: panel D), the control cell line
displayed more elongated and dendritic cells and a
30 criss-cross pattern, changes previously seen shortly
after rodent fibroblasts are treated with TPA (Boreiko
et al., 1980). These changes were, however, much more
dramatic when the R6-PKC3 and R6-PKC5 cells were
treated with TPA (R6-PKC3 and R6-PKC5, Panel D). This
35 was particularly striking with the R6-PKC3 cells (which

express the highest level of PKC) since they displayed very long cytoplasmic processes and numerous refractile cell bodies.

5 By 48 hours following exposure to TPA the morphology of the control cell line R6-C1 had returned to its normal appearance (Figure 4, Panel E). On the other hand, the R6-PKC3 cells, and to a lesser extent the R6-PKC5 cells, continued to display an altered 10 morphology. All of the cell lines were then exposed to a second, fresh dose of TPA (100 ng/ml) and examined 24 hours later (Figure 4, Panel F), i.e., 72 hours after the first dose of TPA. The control cells failed to respond, in terms of morphologic change, to the second 15 dose of TPA whereas the R6-PKC3 cells continued to display their altered morphology as well as an increase in cell density. The R6-PKC5 cells displayed only slight changes in morphology in response to the second dose of TPA.

20

Presumably, the very high level of constitutive production of PKC in the R6-PKC3 cell line is responsible for their exaggerated morphologic response to TPA as well as the failure of these cells to display 25 the usual refractory response to TPA following an initial exposure. In normal cells, the latter response appears to be due to "down-regulation" of endogenous PKC activity. Since the R6-PKC5 cells have an intermediate level of PKC, it is not surprising that 30 their morphologic responses to TPA are intermediate between those of the control cells and the R6-PKC3 cells.

Growth Curves

35

It was also of interest to determine the growth rates of these cells in monolayer culture. Detailed growth curves were performed on R6-C1, R6-PKC3 and R6-PKC5 cells in 10% calf serum and DMEM medium, in the absence and presence of 100 ng/ml TPA. The data obtained are summarized quantitatively in Table 2.

In the absence of TPA, the R6-C1 control cell line displayed the longest doubling time (26.4 hours) and the lowest saturation density (3.4×10^6 cells/plate); the R6-5 cell line had a shorter doubling time (24.9 hours) and a higher saturation density (4.8×10^6 cells/plate); and the R6-PKC3 cell line had the shortest doubling time (24.2 hours) and the highest saturation density (5.7×10^6 cells/plate). The presence of TPA decreased the doubling times, and also increased the saturation densities of all three cell lines, but the enhancement by TPA was particularly striking in the case of R6-PKC3 (Table 2).

20

When the cell lines were maintained in the presence of TPA for a longer period of time, the R6-PKC3 cells, but not the R6PKC5 or R6-C1 cells, showed a decline in cell density. The latter effect was due to the fact that when the R6-PKC3 cells were maintained at high cell density in the presence of TPA they became less adhesive and tended to detach from the plate.

30

Thus, even in the absence of TPA the R6-PKC3 cells, (which have the highest level of PKC), and to a lesser extent the R6-PKC5 cells (which have an intermediate level of PKC), exhibit an enhancement of their growth properties which is even greater than that seen when the R6-C1 control cells are grown in the

presence of TPA. Moreover, in the presence of TPA these differences in growth properties between the control and R6-PKC3 cells are even more striking.

5

Foci Formation

In additional studies, monolayer cultures were maintained at post-confluence for an extended period of time (28 days), with media changes every 3 days, in the absence of TPA. Whereas the control R6-C2 cell line remained a fairly uniform monolayer, after about 21 days the R6-PKC3 cell line developed numerous dense foci which were approximately 0.1-0.3 mm in diameter (Figure 5). Furthermore, the R6-PKC3 cultures displayed numerous cells with a highly vacuolated cytoplasm which were scattered throughout the monolayer, but were not seen in the R6-C2 control culture. When the dense foci seen in the R6-PKC3 culture were picked and further passaged they grew like the parental R6-PKC3 cells and did not display a morphology typical of malignantly transformed cells. It may be surmised that these dense foci, and the vacuolated cells, reflect physiologic rather than genetic changes induced by the high level of PKC activity.

Growth on Soft Agar

I also assayed these cell lines for their ability to form colonies in soft agar, since with rodent cells the acquisition of anchorage-independent growth often correlates with tumorigenicity (Freedman and Shin, 1974). As shown in Figure 6, when 2×10^4 cells were plated in 0.3% soft agar, both the R6-PKC3 and the R6-PKC5 cells formed numerous small colonies, whereas

the control R6-C1 cells (and the parental Rat 6 cell line) failed to grow and persisted as single cells. In addition, when TPA (100 ng/ml) was added to the agar medium, the colony sizes and cloning efficiencies of the R6-PKC3 and RC-PKC5 cells were enhanced (Figure 6 and Table 2), but the R6-C1 cells still failed to grow in agar.

The cloning efficiencies and colony sizes of the R6-PKC3 cultures were always greater than those of the R6-PKC5 cultures, both in the absence and presence of TPA (Table 2), presumably reflecting the higher level of PKC activity in the former cell line. Thus, it is clear that the overproduction of PKC is associated with the acquisition of anchorage-independent growth in Rat 6 cells. The sizes of the colonies formed in agar by the PKC cell lines are smaller than those formed by Rat 6 cells transformed by an activated c-H-ras oncogene, which have a diameter of about 0.5 - 1.0 mm.

20

Further Screening of Activators and Inhibitors of PKC

Additional compounds tested included the tumor promoters teleocidin, aplysiatoxin, and mezerein, all of which are known activators of PKC (O'Brian, et al., CSH, 1985). Furthermore, a known inhibitor of PKC, H-7 (Kawamoto and Hidaka, 1984), also modulated the growth of the cells in the expected manner.

Moreover, this method has been used to establish that the anti-estrogen tamoxifen (O'Brian, et al, Cancer Res., 1985), which inhibits PKC enzyme activity in a cell-free assay, is capable of completely inhibiting the growth in agar of all of the cell lines overproducing PKC. Inhibition of the growth of the

R6-PKC3 cells in agar in the presence of tamoxifen provided critical evidence that tamoxifen could inhibit PKC-mediated stimulation of cellular growth.

5 Furthermore, the concentration of the inhibitor necessary to completely inhibit the growth of each cell line was roughly proportional to the amount of PKC being overproduced in that particular cell line. In
10 other words, there is a direct relationship between the molar amount of inhibitor required to prevent cell growth and the molar amount of PKC present in each cell line.

15 In addition, I have demonstrated the analogous relationship between the molar amounts of PKC activators and the molar amounts of PKC present in cells. In other words, there is a direct relationship between the molar amount of activator required to stimulate cell growth and the molar amount of PKC present in cells. Thus, this work establishes, for the first time, the fact that stable overproduction of a protein in mammalian cells can result in a novel
20 cellular phenotype(s) (in this case anchorage independence) which can be directly modulated by
25 chemical agents which interact with the protein.

Example 2

30 If one were interested in screening for a potent inhibitor of the c-H-ras oncogene product (the p21 protein) then one would generate cells which grow well in soft agar with appropriate media conditions when p21 is stably overproduced at a certain level, but not at all when p21 is present at wild type levels. Screening for a potent p21 inhibitor could then be performed as
35 described in Example 1 above.

Example 3

The same basic techniques would also apply to genes (or cDNA sequences) which have been mutated either by laboratory design (e.g. site-directed mutagenesis) or as a result of naturally occurring events. Thus, any of the known point mutations in the ras oncogene which result in greater capability by the mutated gene to transform normal cells to cancerous ones could be employed in the same basic procedures as described above

Further Modifications

Use of any expression vector capable of stably overexpressing a given gene in a recipient cell could be used with success in the procedures described herein. The retroviral vector which I used here was particularly well suited to the problem since I had designed it specifically for these purposes. However, other similar vector systems would work. Also, one could do co-transfection of an experimental gene inserted in one plasmid vector along with a second plasmid containing the selectable marker gene (rather than having both the experimental gene and the selectable marker gene on the same plasmid vector). This is more difficult and less efficient than using the pMV7 vector, but it would work to some extent.

Any growth medium, in addition to soft agar or methocel, which tends to prohibit the growth of normal, non-transformed cells, could also be used.

A culture of E. coli DH1 bearing the plasmid denoted pMV7-RP58 (pMV7-PKC beta1), was deposited under

the Budapest Treaty with the American Type Culture Collection on February 11, 1988, ATCC No. 67654. The deposit of this plasmid is not to be construed as an admission that the deposit is required for enablement or that the disclosure is limited to the deposited vector or gene.

TABLE 1(a)

PKC Activity and Phorbol Ester Binding in Rat 6 Cells
Infected with pMV7 or pMV7-PKC β 1 Constructs

		PKC Activity		^{3}H - P D B U Binding
	Cell Line	Specific Activity (pmol/min/mg prot)	Fold Increase Relative to Control	(pmol/ 10^6 cells)
10	R6-C1	100	—	1.6
15	R6-C2	85	—	1.3
20	R6-C3	150	—	1.5
	mean + s.d.	100 + 34	1	
25	R6-PKC1	2480	23	12.7
	R6-PKC2	85	1	ND
30	R6-PKC3	5840	53	9.9
	R6-PKC4	190	2	0.7
	R6-PKC5	2200	20	5.8
35	R6-PKC6	4600	42	7.1
	R6-PKC7	2150	20	ND
40	R6-PKC8	3280	30	ND
	R6-PKC9	4990	45	ND
	R6-PKC10	5050	46	ND

TABLE 1(b)

PKC Activity in NIH-3T3 Cell Lines
Infected with pMV7 or pMV7-PKC β 1 Constructs

	NIH-3T3 Cell lines Increase (Controls)	PKC Specific Activity (pmol/min/mg prot)	Fold Relative to Control
10	Control		
	3T3-C1	110	-----
	3T3-C2	150	-----
	3T3-C3	90	-----
15	mean +/- s.d. (control lines)	115 +/- 30	
	-----	-----	-----
20	NIH-3T3 PKC-Overproducing Cell Lines		
	3T3-PKC1	2570	22
	3T3-PKC2	3640	32
25	3T3-PKC3	1960	17
	3T3-PKC4	1240	11
	3T3-PKC5	4190	36
	3T3-PKC6	2110	18
30	3T3-PKC7	5050	44

Table 1(c)

PKC Activity in C3H-10T1/2 Cell Lines
 Infected with pMV7 or pMV7-PKCbeta Constructs

	C3H-10T1/2 Cell lines	PKC Specific Activity (pmol/min/mg prot)	Fold Relative to Control
10	Increase (Controls)		
15	Control		
	C3H-C1	115	-----
	C3H-C2	155	-----
	C3H-C3	130	-----
	C3H-C4	185	-----
	mean +/- s.d.	145 +/- 30	
	-----	-----	-----
20	C3H-10T1/2 PKC-Overproducing Cell Lines		
25	C3H-PKC1	2340	16
	C3H-PKC2	5010	35
	C3H-PKC3	950	7
	C3H-PKC4	1360	9
	C3H-PKC5	4340	30
	C3H-PKC6	7460	51

30 Legend to Table 1

35 Control cell lines were obtained by infecting rat-
 6-fibroblast, NIH-3T3 and C3H-10T1/2 cells with the
 pMV7 vector itself (lacking the PKC cDNA insert)
 whereas the PKC-overproducing cell lines were obtained
 from rat-6-fibroblast, NIH-3T3 and C3H-10T1/2 cells
 infected with the pMV7-PKCbeta construct, as described
 above. Total PKC activity was partially purified from
 40 each of the cell lines and assayed in the presence of 1
 mM Ca²⁺ and 80 ug/ml phosphatidylserine, using the
 synthetic peptide R-K-R-T-L-R-R-L as substrate.
 Specific activity is reported as the amount of
 incorporation of ³²P into the synthetic peptide
 45 substrate per milligram of protein per minute. All
 assays were done in duplicate and varied by less than
 10%.

TABLE 2

5 GROWTH PROPERTIES OF RAT 6 CELL LINES OVERPRODUCING PKC
AND THEIR RESPONSES TO TPA TREATMENT

		Growth in Culture					
		Monolayer			Agar		
		Cell Line	TPA Add	Doubling Time (hrs)	Saturat. Density ($\times 10^6$)	Effic. (%)	Colony Size (mm)
10					:	:	:
15	R6C1 (control)	-	-	26.4	3.4	: 0	---
		+	+	24.6	4.2	: 0	---
	R6-PKC3 (test)	-	-	24.2	5.7	: 25.1	0.10 - 0.15
20		+	+	21.5	10.0	: 29.7	0.15 - 0.35
25	R6-PKC5 (test)	-	-	24.9	4.8	: 17.3	0.05 - 0.10
		+	+	22.9	7.0	: 34.7	0.10 - 0.15

25 Table 2. The cells were grown as described above. The "doubling times" relate to the initial exponential phase of cell growth and the "saturation density" represents the number of cells per 6 cm plate on day 30 11. The data are taken from the experiment shown in Figure 3.

Table 3

Inhibition of Growth in Agar of PKC-Overproducing
Cell Lines Using Various Inhibitors

	Inhibitor	Cell Line	Conc. Inhibitor (uM)	Effic. of Growth In Agar (%)
10	H-7	R6-PKC3	0	27
	H-7	R6-PKC3	2	25
	H-7	R6-PKC3	5	22
	H-7	R6-PKC3	10	17
15	H-7	R6-PKC3	50	4
	H-7	R6-PKC3	100	0
20	H-7	R6-PKC5	0	20
	H-7	R6-PKC5	2	21
	H-7	R6-PKC5	5	16
	H-7	R6-PKC5	10	4
	H-7	R6-PKC5	50	1
	H-7	R6-PKC5	100	0
25	Tamoxifen	R6-PKC3	0	25
	Tamoxifen	R6-PKC3	5	27
	Tamoxifen	R6-PKC3	20	22
	Tamoxifen	R6-PKC3	50	15
	Tamoxifen	R6-PKC3	100	6
	Tamoxifen	R6-PKC3	200	0
30	Tamoxifen	R6-PKC5	0	19
	Tamoxifen	R6-PKC5	5	19
	Tamoxifen	R6-PKC5	20	17
	Tamoxifen	R6-PKC5	50	8
	Tamoxifen	R6-PKC5	100	0
	Tamoxifen	R6-PKC5	200	0
35	Staurosporine	R6-PKC3	0	29
	Staurosporine	R6-PKC3	0.001	29
	Staurosporine	R6-PKC3	0.005	26
	Staurosporine	R6-PKC3	0.010	15
	Staurosporine	R6-PKC3	0.050	7
	Staurosporine	R6-PKC3	0.250	0
40	Staurosporine	R6-PKC5	0	22
	Staurosporine	R6-PKC5	0.001	21
	Staurosporine	R6-PKC5	0.005	17
	Staurosporine	R6-PKC5	0.010	10
	Staurosporine	R6-PKC5	0.050	2
	Staurosporine	R6-PKC5	0.250	0
45	Staurosporine	R6-PKC3	0	22
	Staurosporine	R6-PKC3	0.001	21
	Staurosporine	R6-PKC3	0.005	17
	Staurosporine	R6-PKC3	0.010	10
	Staurosporine	R6-PKC3	0.050	2
	Staurosporine	R6-PKC3	0.250	0

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CLAIMS

1. A method of determining whether a substance is an inhibitor or activator of a protein whose production by a cell evokes a responsive change in a phenotypic characteristic other than the level of said protein in said cell per se, which comprises:
 - (a) providing a first cell line which produces said protein and exhibits said phenotypic response to the protein;
 - (b) providing a second cell line which produces the protein at a lower level than the first cell line, or does not produce the protein at all, and which exhibits said phenotypic response to the protein to a lesser degree or not at all;
 - (c) incubating the substance with the first and second cell lines; and
 - (d) comparing the phenotypic response of the first cell line to the substance with the phenotypic response of the second cell line to the substance.
2. The method of claim 1 wherein the response is one observable with the naked eye.
3. The method of claim 1 wherein the response is a change in a cultural or morphological characteristic of the cell.

4. The method of claim 1 wherein the response is a change in the ability of the cell line to grow in an anchorage-independent fashion.

5 5. The method of claim 1 wherein the response is a change in the ability of the cell line to grow on soft agar.

10 6. The method of claim 1 wherein the response is a change in foci formation in cell culture.

7. The method of claim 1 wherein the response is a change in the ability of the cells to take up a selected stain.

15 8. The method of claim 1 in which the protein is an enzyme.

20 9. The method of claim 8 wherein increased activity of the enzyme is correlated with increased tumorigenesis.

25 10. The method of claim 9 in which the enzyme is a protein kinase C enzyme or a fragment, domain or subunit of a receptor which has protein kinase C activity.

11. The method of claim 9 wherein the enzyme is ornithine decarboxylase.

30 12. The method of claim 9 in which the protein is the expression product of an oncogene.

13. The method of claim 1 in which the substance

is a suspected inhibitor of the biological activity of the protein.

5 14. The method of claim 1 in which the substance is a suspected activator of the biological activity of the protein.

10 15. The method of claim 1, wherein said first cell line is obtained by introducing a gene encoding the protein of interest into a host cell, said gene being under the control of a promoter functional in the host cell, whereby said gene is expressed.

15 16. The method of claim 15, wherein the gene is introduced into the host cell by means of a first genetic vector into which the gene has been inserted, and said second cell line is obtained by introducing into a similar host cell a second genetic vector essentially identical to the first genetic vector except that it does not bear said gene insert.

20 17. The method of claim 15 wherein the gene is introduced into the host cell by means of a retroviral vector.

25 18. The method of claim 15 in which the host cell line essentially does not produce the protein.

30 19. The method of claim 15 in which the host cell line is a rat-6 fibroblast cell line.

20. The method of claim 3 in which the response is a change in the differentiation state of the cell.

21. A test kit for determining whether a substance is an inhibitor or activator of a protein whose production evokes a responsive change in a phenotypic characteristic other than level of said protein in said cell per se, which comprises:

(a) a first cell line which produces the protein and exhibits said phenotypic response thereto; and

(b) a second cell line which produces the protein at a lower level than the first cell line, or does not produce the protein, and which exhibits said phenotypic response to the protein to a lesser degree or not at all.

15 22. The test kit of claim 21, wherein the level of production of the protein in the first cell line is at least five times the level of production of the protein in the second line.

20 23. The test kit of claim 21, wherein the phenotypic response to expression of the protein is selected from the group consisting of changes in growth rate, saturation density, plating efficiency in soft agar, colony size in soft agar, and combinations thereof.

25 24. The method of claim 1 wherein the response is a change in an antigenic characteristic of the cell.

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FIG. I.

10	20	30	40	50	60
*	*	*	*	*	*
GAA	TTC	CGC	CTC	TCC	GGG
70	80	90	100	110	120
*	*	*	*	*	*
GGG	GCT	CCC	CCC	AGT	CCC
130	140	150	160	170	180
*	*	*	*	*	*
AGC	GAG	GGC	GAG	GAG	AGC
Ser	Glu	Gly	Glu	Glu	Ser
190	200	210	220	230	240
*	*	*	*	*	*
GTG	CAC	GAG	GTG	AAG	AAC
Val	His	Glu	Val	Lys	Asn
250	260	270	280	290	300
*	*	*	*	*	*
AGC	CAC	TGC	ACC	GAC	TTC
Ser	His	Cys	Thr	Asp	Phe
310	320	330	340	350	360
*	*	*	*	*	*
TGC	TTT	GTT	GTA	CAC	AAG
Cys	Phe	Val	Val	His	Lys
370	380	390	400	410	420
*	*	*	*	*	*
AAG	GGC	CCG	GCC	TCT	GAT
Lys	Gly	Pro	Ala	Ser	Asp
430	440	450	460	470	480
*	*	*	*	*	*
AGC	CCT	ACC	TTC	TGT	GAC
Ser	Pro	Thr	Phe	Cys	Asp
490	500	510	520	530	540
*	*	*	*	*	*
AAA	TGC	GAC	ACC	TGT	ATG
Lys	Cys	Asp	Thr	Cys	Met
550	560	570	580	590	600
*	*	*	*	*	*
TGT	GGC	ACC	GAC	CAC	ACA
Cys	Gly	Thr	Asp	His	Thr

Glu Arg Arg Gly Arg Ile Tyr Ile Gln Ala His Ile Asp Arg

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FIG. I. CONT.

610	620	630	640	650	660
*	*	*	*	*	*
GAG GTC CTC ATC GTT GTT GTA AGA GAT GCT AAA AAT CTG GTA CCT ATG GAC CCC AAC GGC					
Glu Val Leu Ile Val Val Val Arg Asp Ala Lys Asn Leu Val Pro Met Asp Pro Asn Gly					
670	680	690	700	710	720
*	*	*	*	*	*
TTG TCA GAT CCC TAC GTA AAA CTG AAA CTG ATC CCT GAT CCC AAA AGT GAG AGC AAG CAG					
Leu Ser Asp Pro Tyr Val Lys Leu Lys Leu Ile Pro Asp Pro Lys Ser Glu Ser Lys Gln					
730	740	750	760	770	780
*	*	*	*	*	*
AAG ACC AAG ACT ATC AAA TGC TCC CTC AAC CCG GAG TGG AAC GAA ACC TTC AGA TTT CAG					
Lys Thr Lys Thr Ile Lys Cys Ser Leu Asn Pro Glu Trp Asn Glu Thr Phe Arg Phe Gln					
790	800	810	820	830	840
*	*	*	*	*	*
CTG AAG GAA TCA GAC AAA GAC AGA AGA CTG TCC GTA GAG ATC TGG GAT TGG GAC CTG ACC					
Leu Lys Glu Ser Asp Lys Asp Arg Arg Leu Ser Val Glu Ile Trp Asp Trp Asp Leu Thr					
850	860	870	880	890	900
*	*	*	*	*	*
AGC AGG AAT GAC TTC ATG GGA TCT CTG TCG TTT GGG ATT TCA GAA CTA CAG AAA GCC GGA					
Ser Arg Asn Asp Phe Met Gly Ser Leu Ser Phe Gly Ile Ser Glu Leu Gln Lys Ala Gly					
910	920	930	940	950	960
*	*	*	*	*	*
GTG GAT GGC TGG TTC AAG TTA CTA AGC CAG GAA GAA GGC GAG TAC TTT AAT GTG CCG GTG					
Val Asp Gly Trp Phe Lys Leu Leu Ser Gln Glu Glu Gly Glu Tyr Phe Asn Val Pro Val					
970	980	990	1000	1010	1020
*	*	*	*	*	*
CCG CCG GAA GAA AGC GAG GGC AAT GAA GAG CTG CGG CAG AAG TTT GAG AGA GCC AAG ATT					
Pro Pro Glu Glu Ser Glu Gly Asn Glu Glu Leu Arg Gln Lys Phe Glu Arg Ala Lys Ile					
1030	1040	1050	1060	1070	1080
*	*	*	*	*	*
GGC CAA GGT ACC AAG GCT CCA GAA GAA AAG ACA GCG AAC ACT ATA TCC AAA TTT GAC AAC					
Gly Gln Gly Thr Lys Ala Pro Glu Glu Lys Thr Ala Asn Thr Ile Ser Lys Phe Asp Asn					
1090	1100	1110	1120	1130	1140
*	*	*	*	*	*
AAT GGC AAC AGG GAC CGG ATG AAA CTG ACC GAT TTT AAC TTC CTG ATG GTG CTG GGG AAA					
Asn Gly Asn Arg Asp Arg Met Lys Leu Thr Asp Phe Asn Phe Leu Met Val Leu Gly Lys					
1150	1160	1170	1180	1190	1200
*	*	*	*	*	*
GGC AGC TTT GGC AAG GTC ATG CTC TCA GAG CGG AAG GGT ACA GAT GAA CTC TAT GCC GTG					

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FIG. I. CONT.

Gly	Ser	Phe	Gly	Lys	Val	Met	Leu	Ser	Glu	Arg	Lys	Gly	Thr	Asp	Glu	Leu	Tyr	Ala	Val
1210		1220		1230		1240		1250		1260									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
AAG	ATC	CTG	AAG	AAA	GAT	GTG	GTG	ATC	CAA	GAT	GAC	GAT	GTG	GAG	TGC	ACA	ATG	GTG	GAG
Lys	Ile	Leu	Lys	Lys	Asp	Val	Val	Ile	Gln	Asp	Asp	Asp	Val	Glu	Cys	Thr	Met	Val	Glu
1270		1280		1290		1300		1310		1320									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
AAG	AGG	GTG	CTG	GCC	CTG	CCT	GGG	AAG	CCC	CCA	TTC	CTG	ACT	CAG	CTC	CAT	TCC	TGC	TTC
Lys	Arg	Val	Leu	Ala	Leu	Pro	Gly	Lys	Pro	Pro	Phe	Leu	Thr	Gln	Leu	His	Ser	Cys	Phe
1330		1340		1350		1360		1370		1380									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CAG	ACC	ATG	GAC	CGC	CTC	TAC	TTT	GTG	ATG	GAG	TAT	GTG	AAC	GGG	GGC	GAC	CTC	ATG	TAC
Gln	Thr	Met	Asp	Arg	Leu	Tyr	Phe	Val	Met	Glu	Tyr	Val	Asn	Gly	Gly	Asp	Leu	Met	Tyr
1390		1400		1410		1420		1430		1440									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CAC	ATC	CAA	CAA	GTT	GGC	CGT	TTC	AAG	GAG	CCC	CAT	GCT	GTA	TTT	TAC	GCT	GCA	GAG	ATT
His	Ile	Gln	Gln	Val	Gly	Arg	Phe	Lys	Glu	Pro	His	Ala	Val	Phe	Tyr	Ala	Ala	Glu	Ile
1450		1460		1470		1480		1490		1500									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
GCC	ATC	GGT	CTT	TTC	TTC	TTG	CAG	AGC	AAG	GGC	ATC	ATT	TAC	CGT	GAC	CTG	AAA	CTT	GAC
Ala	Ile	Gly	Leu	Phe	Phe	Leu	Gln	Ser	Lys	Gly	Ile	Ile	Tyr	Arg	Asp	Leu	Lys	Leu	Asp
1510		1520		1530		1540		1550		1560									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
AAC	GTG	ATG	CTG	GAT	TCC	GAG	GGG	CAC	ATC	AAA	ATC	GCT	GAC	TTT	GGC	ATG	TGT	AAA	GAG
Asn	Val	Met	Leu	Asp	Ser	Glu	Gly	His	Ile	Lys	Ile	Ala	Asp	Phe	Gly	Met	Cys	Lys	Glu
1570		1580		1590		1600		1610		1620									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
AAT	ATC	TGG	GAT	GGG	GTG	ACA	ACC	AAG	ACA	TTC	TGT	GGC	ACT	CCA	GAC	TAC	ATT	GCC	CCA
Asn	Ile	Trp	Asp	Gly	Val	Thr	Thr	Lys	Thr	Phe	Cys	Gly	Thr	Pro	Asp	Tyr	Ile	Ala	Pro
1630		1640		1650		1660		1670		1680									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
GAG	ATC	ATT	GCT	TAT	CAG	CCC	TAC	GGA	AAG	TCT	GTG	GAC	TGG	TGG	GCG	TTT	GGA	GTC	CTG
Glu	Ile	Ile	Ala	Tyr	Gln	Pro	Tyr	Gly	Lys	Ser	Val	Asp	Trp	Trp	Ala	Phe	Gly	Val	Leu
1690		1700		1710		1720		1730		1740									
*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
CTG	TAT	GAA	ATG	TTG	GCT	GGC	CAG	GCA	CCT	TTT	GAA	GGG	GAG	GAT	GAG	GAT	GAA	CTC	TTC
Leu	Tyr	Glu	Met	Leu	Ala	Gly	Gln	Ala	Pro	Phe	Glu	Gly	Glu	Asp	Glu	Asp	Glu	Leu	Phe
1750		1760		1770		1780		1790		1800									

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FIG. I. CONT.

CAG	TCA	ATC	ATG	GAG	CAC	AAC	GTG	GCG	TAT	CCC	AAG	TCC	ATG	TCT	AAG	GAA	GCT	GTG	GCA
Gln	Ser	Ile	Met	Glu	His	Asn	Val	Ala	Tyr	Pro	Lys	Ser	Met	Ser	Lys	Glu	Ala	Val	Ala
1810	1820	1830	1840	1850	1860														
*	*	*	*	*	*														*
ATC	TGC	AAA	GGG	CTA	ATG	ACC	AAA	CAC	CCA	GGC	AAG	CGC	CTG	GGT	TGT	GGG	CCT	GAA	GGG
Ile	Cys	Lys	Gly	Leu	Met	Thr	Lys	His	Pro	Gly	Lys	Arg	Leu	Gly	Cys	Gly	Pro	Glu	Gly
1870	1880	1890	1900	1910	1920														
*	*	*	*	*	*														*
GAA	CGA	GAC	ATT	AAG	GAG	CAT	GCA	TTT	TTC	CGG	TAT	ATC	GAC	TGG	GAG	AAA	CTC	GAA	CGC
Glu	Arg	Asp	Ile	Lys	Glu	His	Ala	Phe	Phe	Arg	Tyr	Ile	Asp	Trp	Glu	Lys	Leu	Glu	Arg
1930	1940	1950	1960	1970	1980														
*	*	*	*	*	*														*
AAG	GAG	ATT	CAG	CCA	CCT	TAT	AAA	CCA	AAA	GCT	AGA	GAC	AAG	CGA	GAC	ACC	TCC	AAC	TTC
Lys	Glu	Ile	Gln	Pro	Pro	Tyr	Lys	Pro	Lys	Ala	Arg	Asp	Lys	Arg	Asp	Thr	Ser	Asn	Phe
1990	2000	2010	2020	2030	2040														
*	*	*	*	*	*														*
GAC	AAA	GAG	TTC	ACC	AGG	CAG	CCT	GTG	GAA	CTG	ACT	CCC	ACT	GAC	AAA	CTC	TTC	ATC	ATG
Asp	Lys	Glu	Phe	Thr	Arg	Gln	Pro	Val	Glu	Leu	Thr	Pro	Thr	Asp	Lys	Leu	Phe	Ile	Met
2050	2060	2070	2080	2090	2100														
*	*	*	*	*	*														*
AAC	TTG	GAC	CAA	AAT	GAA	TTT	GCT	GGC	TTC	TCG	TAT	ACT	AAC	CCA	GAG	TTT	GTC	ATT	AAT
Asn	Leu	Asp	Gln	Asn	Glu	Phe	Ala	Gly	Phe	Ser	Tyr	Thr	Asn	Pro	Glu	Phe	Val	Ile	Asn
2110	2120	2130	2140	2150	2160														
*	*	*	*	*	*														*
GTG	TAG	GTG	AAT	GCA	GAT	TCC	ATC	GCT	GAG	CCT	GTG	TGT	AAG	GCT	GCA	GCG	TGA	ATG	TCT
Val	---																		
2170	2180	2190	2200	2210	2220														
*	*	*	*	*	*														*
ATT	ATC	AAT	TCC	AGT	CTT	CCA	GGA	TTC	ATG	GTG	CCT	CTG	TTG	GCA	TCC	GTC	ATG	TGG	AGA
2230	2240	2250	2260	2270	2280														
*	*	*	*	*	*														*
GCT	TGT	CTT	AGA	GGG	CTT	TTC	TTT	GTA	TGT	ATA	GCT	TGC	TAG	TTT	GTT	TTC	TAC	ATT	TCA
2290	2300	2310	2320	2330	2340														
*	*	*	*	*	*														*
AAA	TGT	TTA	GTT	TAG	AAT	AAG	TGC	ATT	GCC	CAC	TGA	TAG	AGG	TAC	AAT	TTT	CCA	GAC	TTC

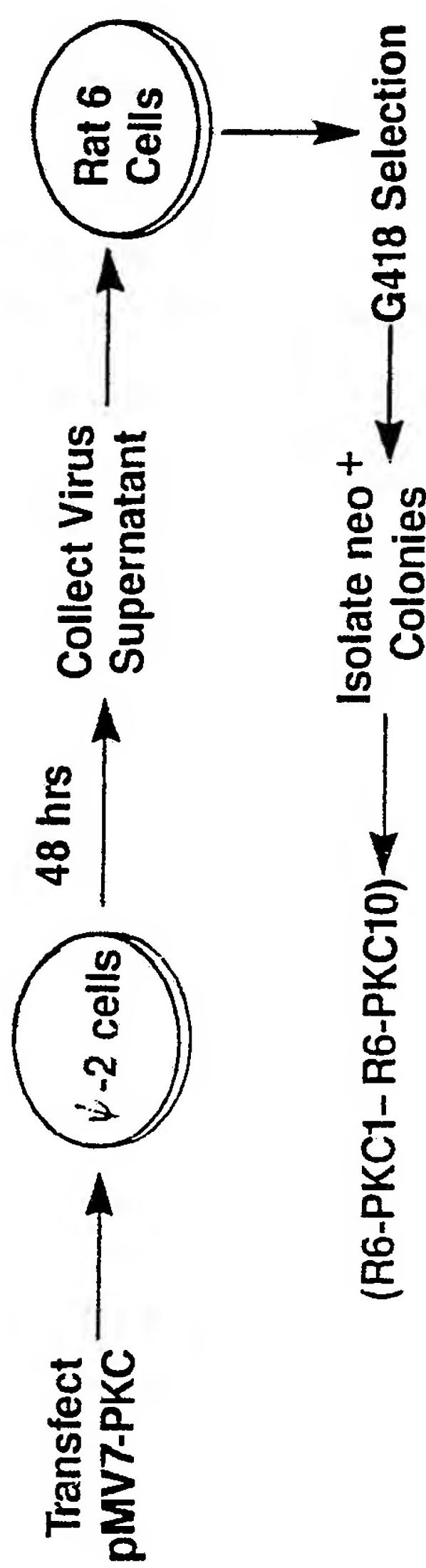
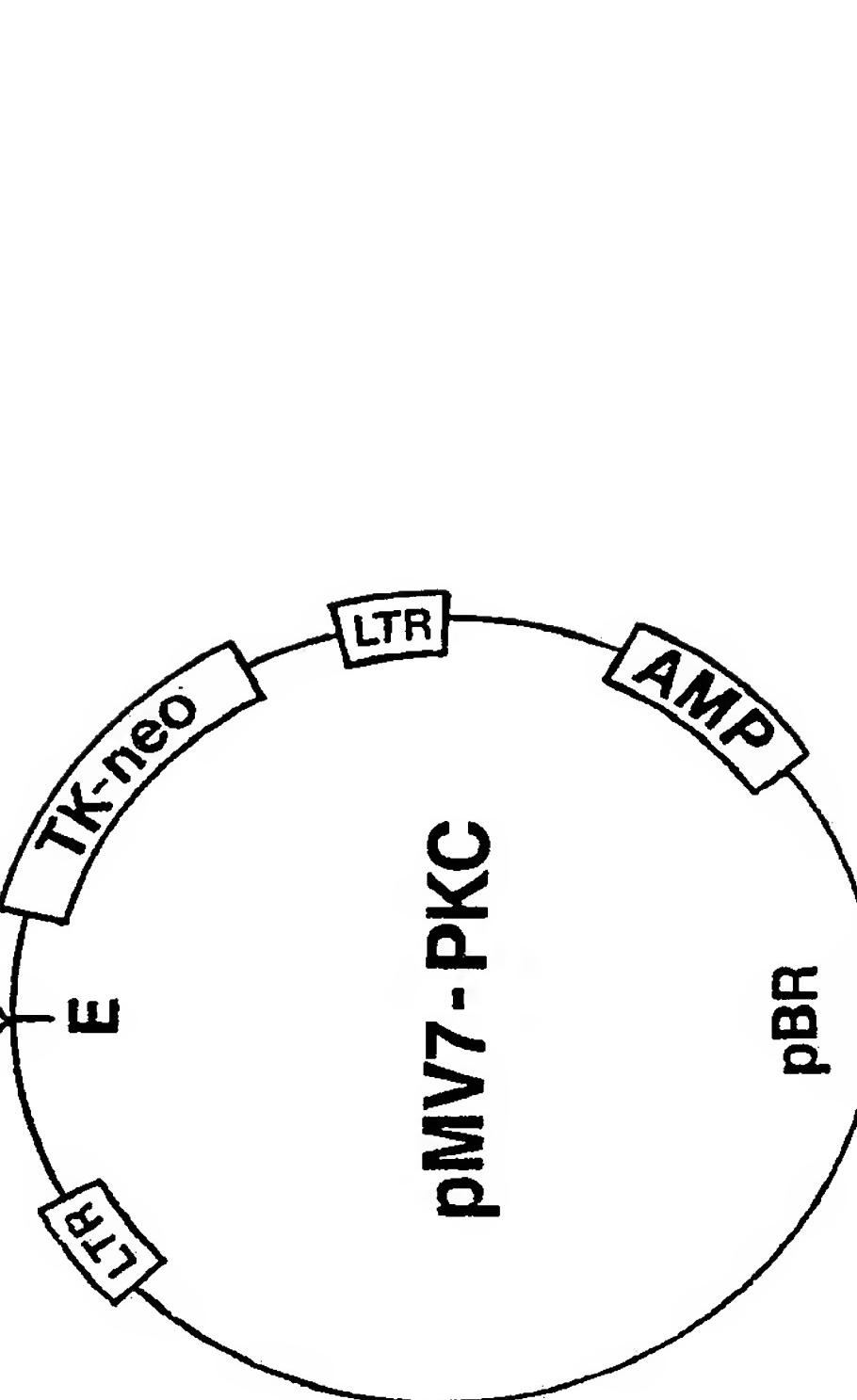
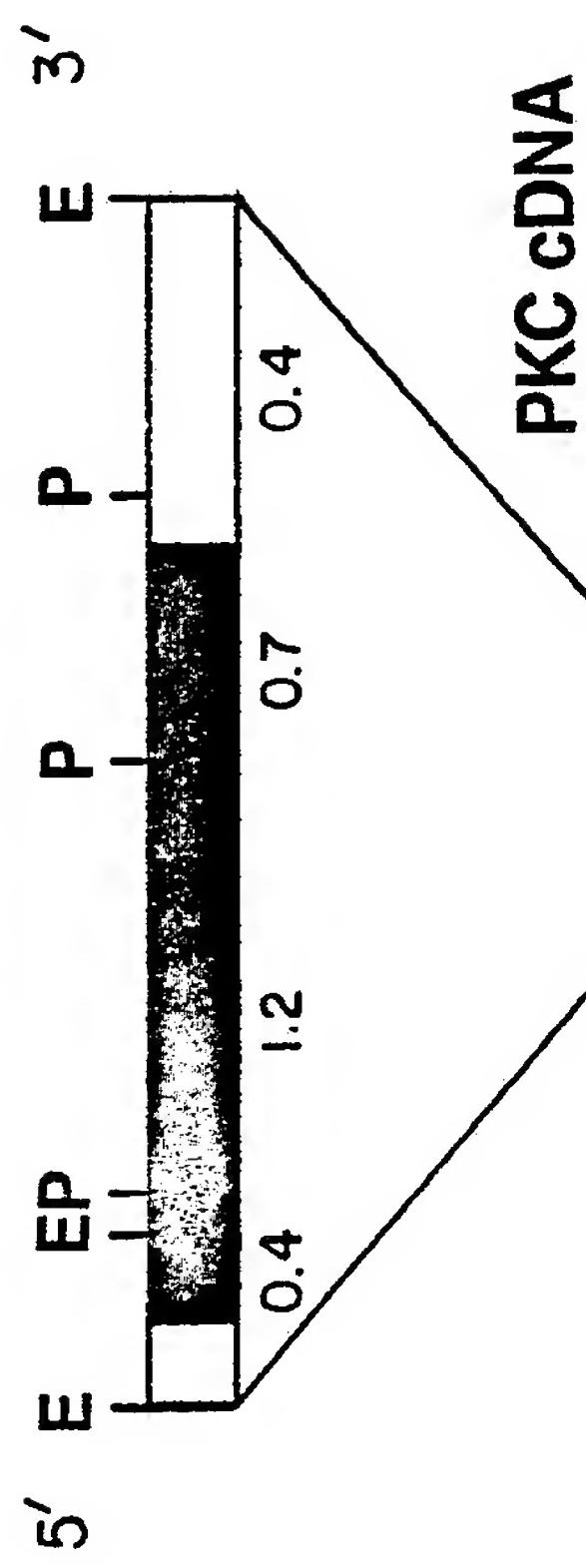
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FIG. I. CONT.

2350	2360	2370	2380	2390	2400
*	*	*	*	*	*
CAG AAA CTC ATC CAA TGA ACC AAC AGT GTC AAA ACT TAA CTG TGT CCG ATA CCA AAA TGC					
2410	2420	2430	2440	2450	2460
*	*	*	*	*	*
TTC AGT ATT TGT AAT TTT TAA AGT CAG ATG CTG ATG TTC CTG GTC AAA GTT TTT ACA GTT					
2470	2480	2490	2500	2510	2520
*	*	*	*	*	*
ACT CTC GAA TAT CTC CTT TGA ATG CTA CCT AAG CAT GAC CGG TAT TTT TAA AAG TTG TGA					
2530	2540	2550	2560	2570	2580
*	*	*	*	*	*
GTA AGC TTT GCA GTT ACT GTG AAC TCT TGT CTC TTG GAG GAA CTT TTT GTT TAA GAA TTG					
2590	2600				
GTA TGA TTA AAC TGA ATT CT	*				

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|R6-C1| |R6-C2| |R6-C3| |R6-PKC1| |R6-PKC2| |R6-PKC3| |R6-PKC4| |R6-PKC5| |R6-PKC6|

FIG. 2 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18

200—

SUBSTITUTE SHEET

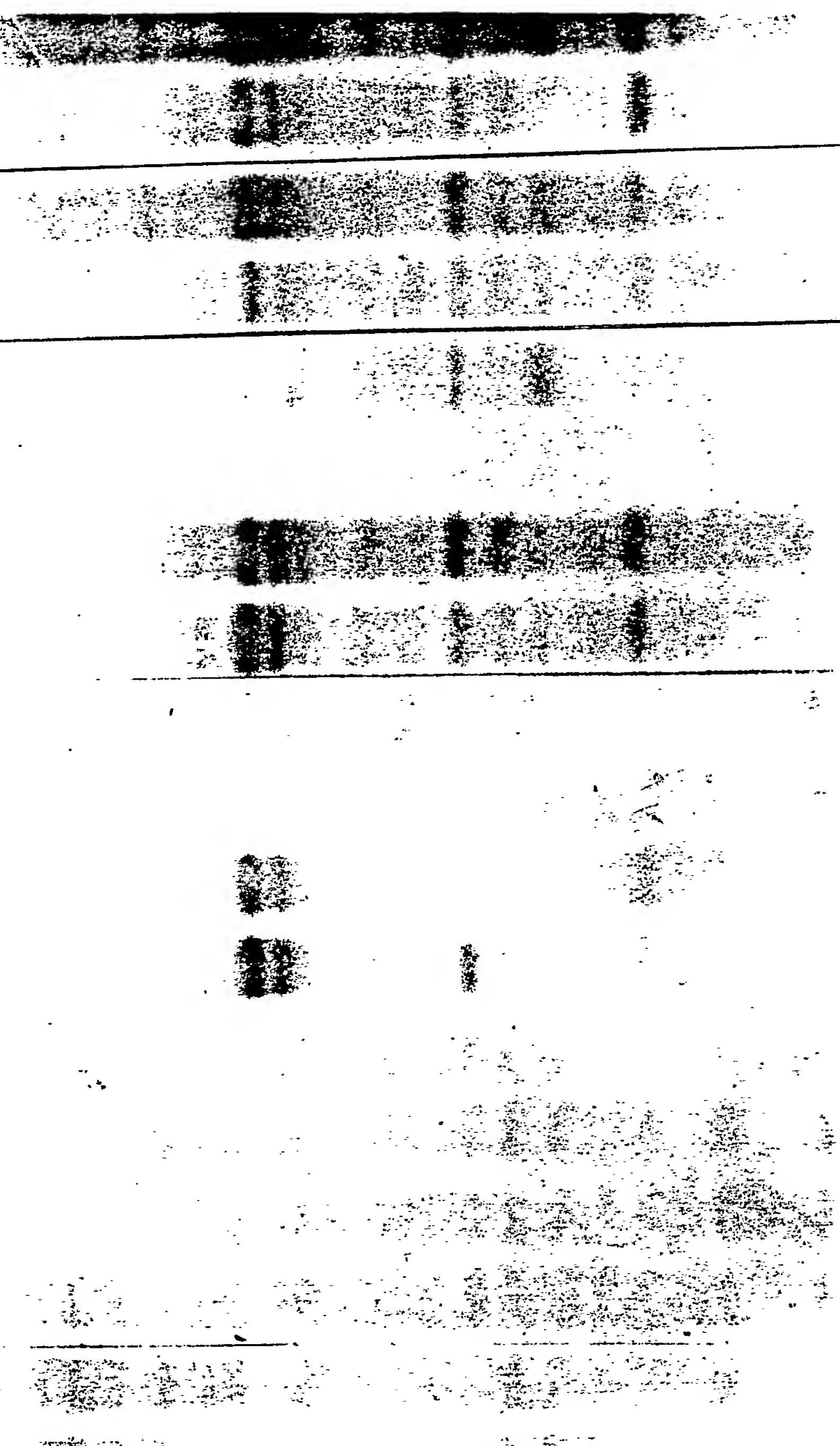
97—



68—

43—

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FIG. 3



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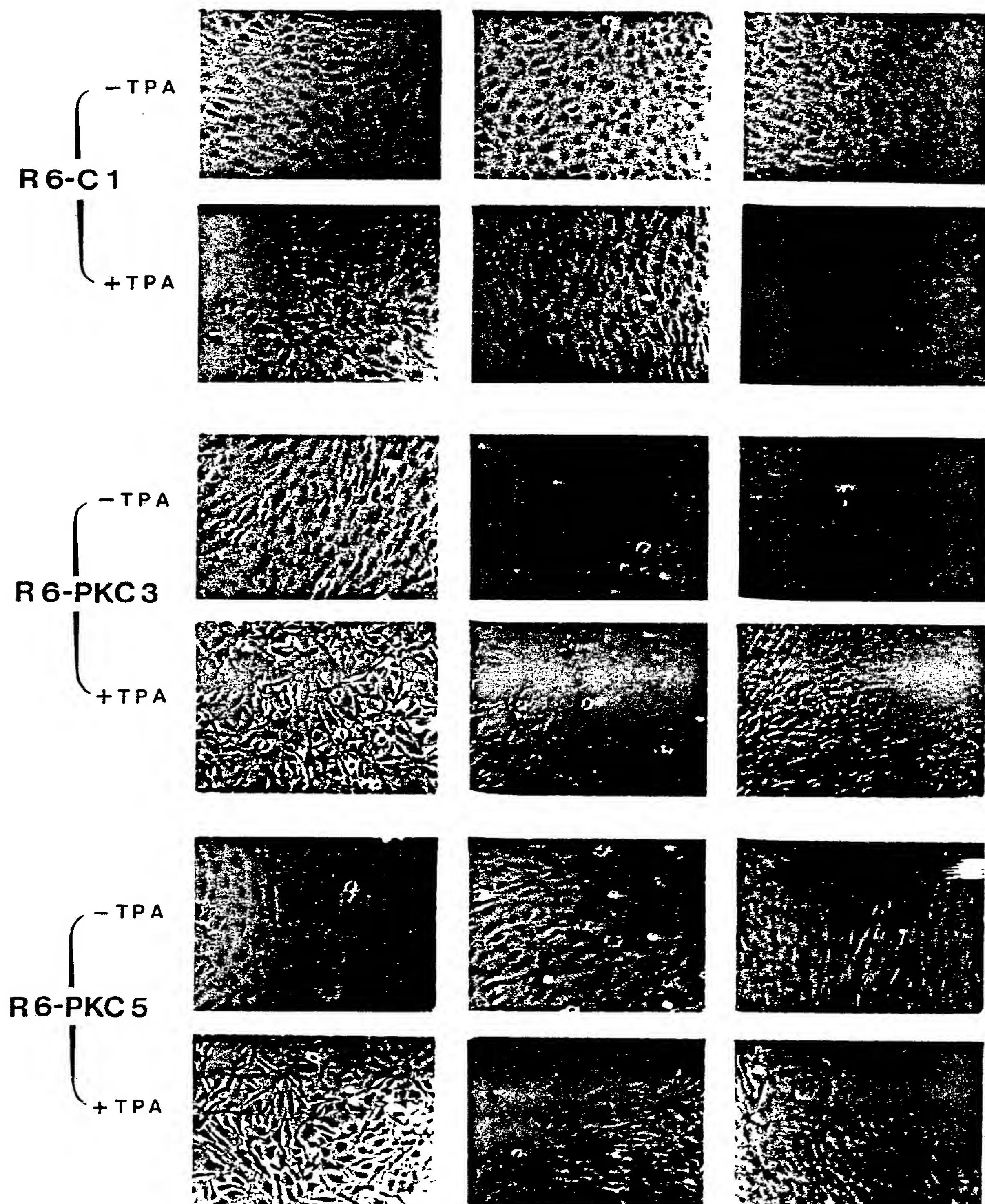
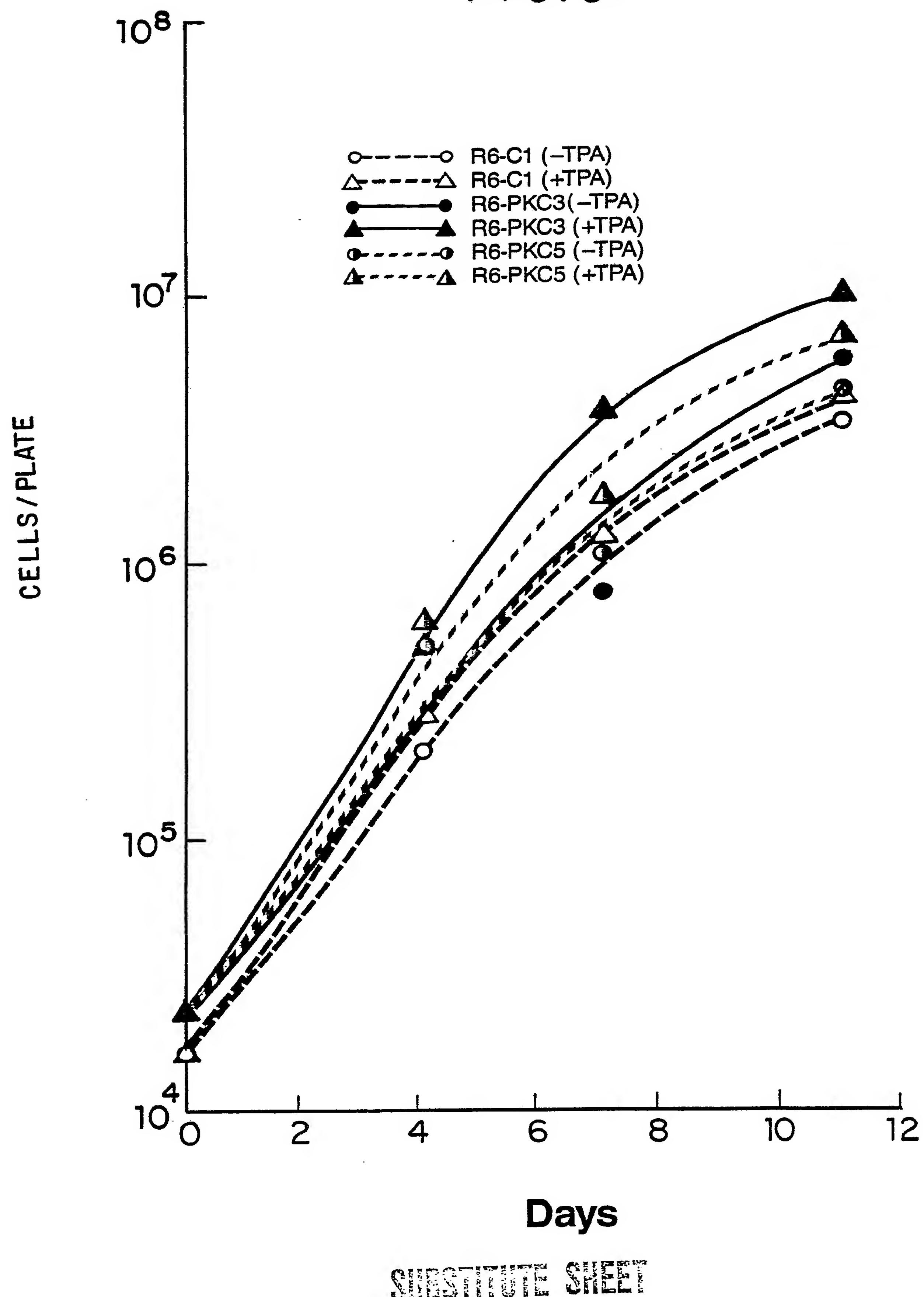


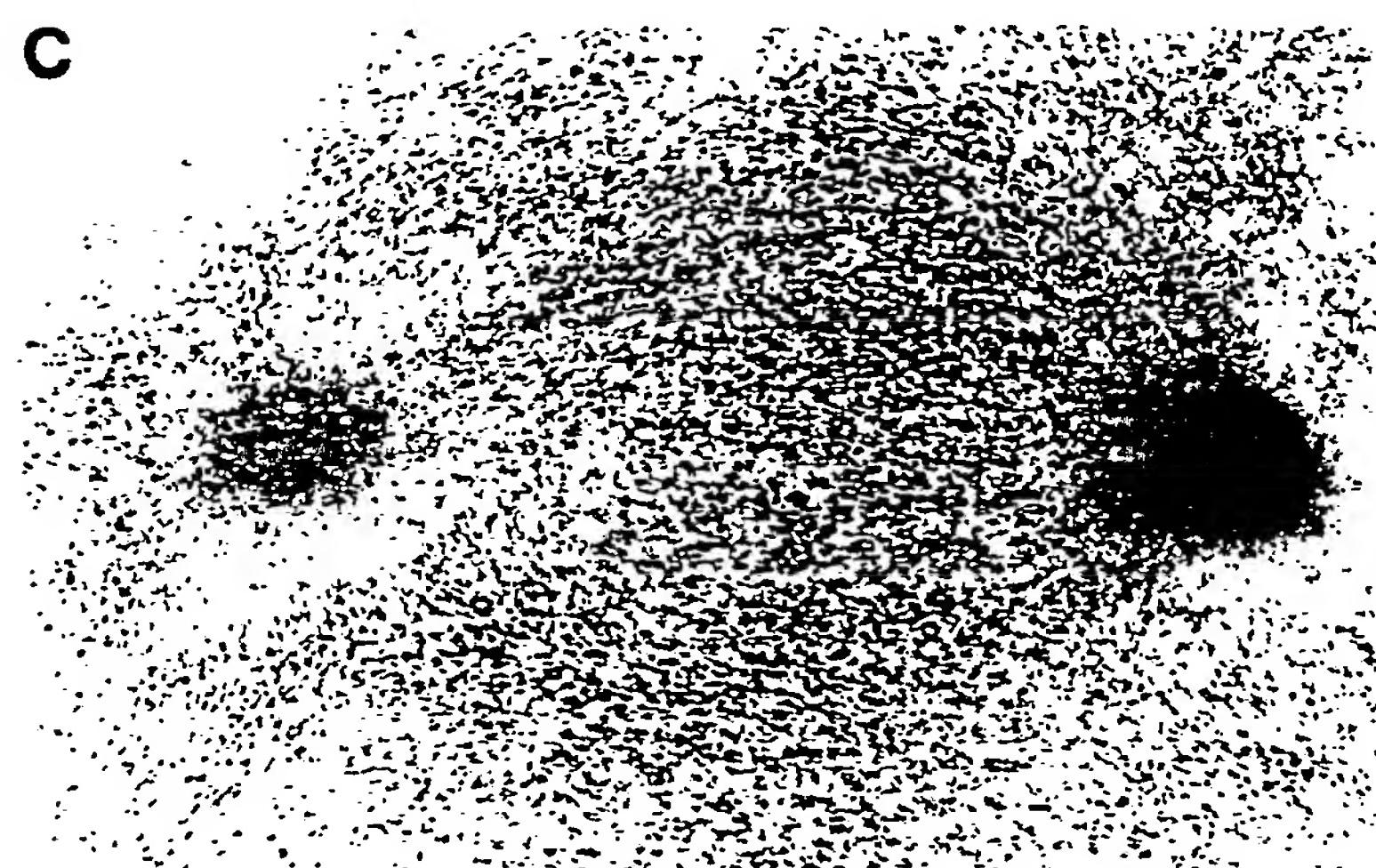
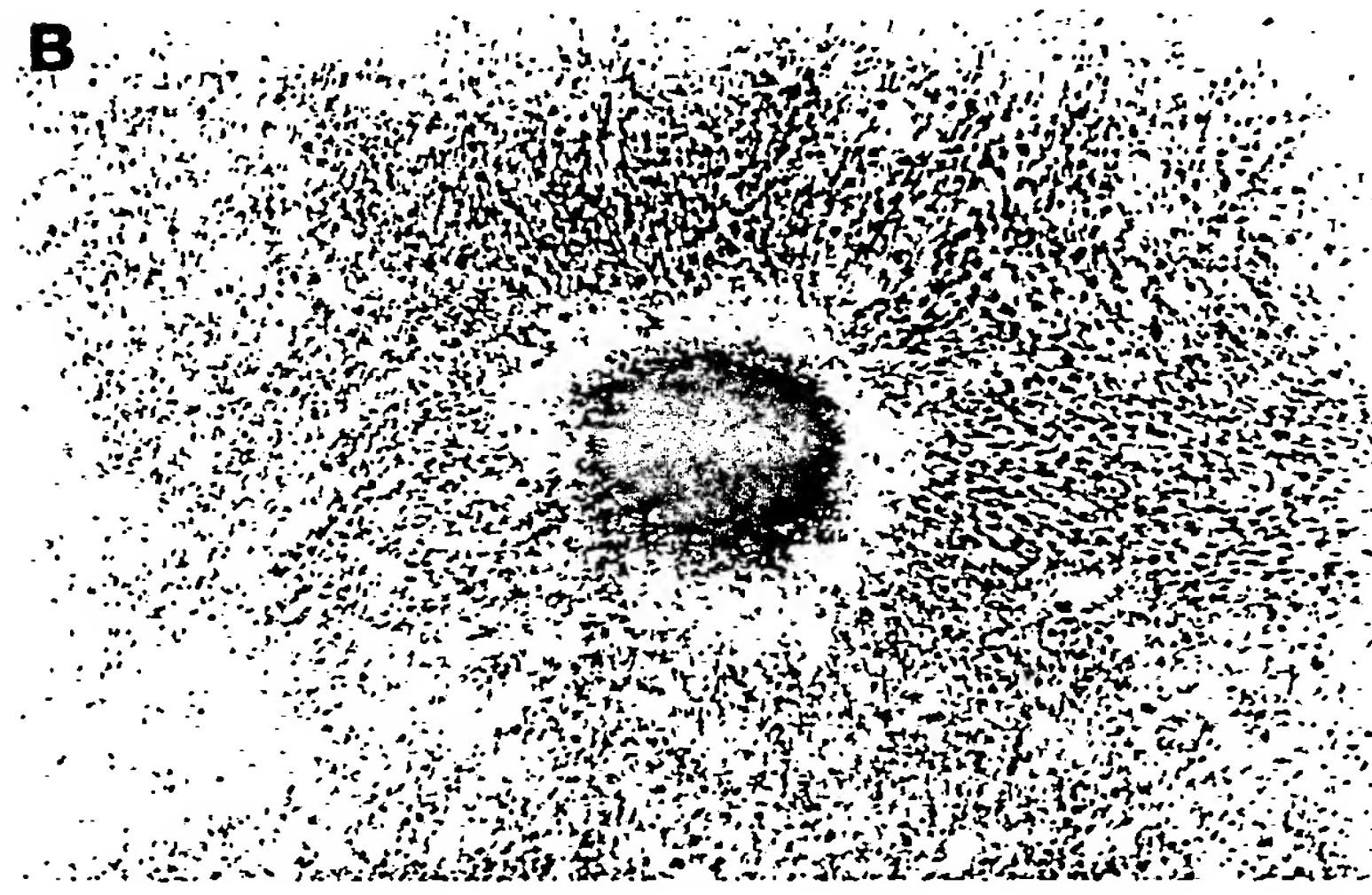
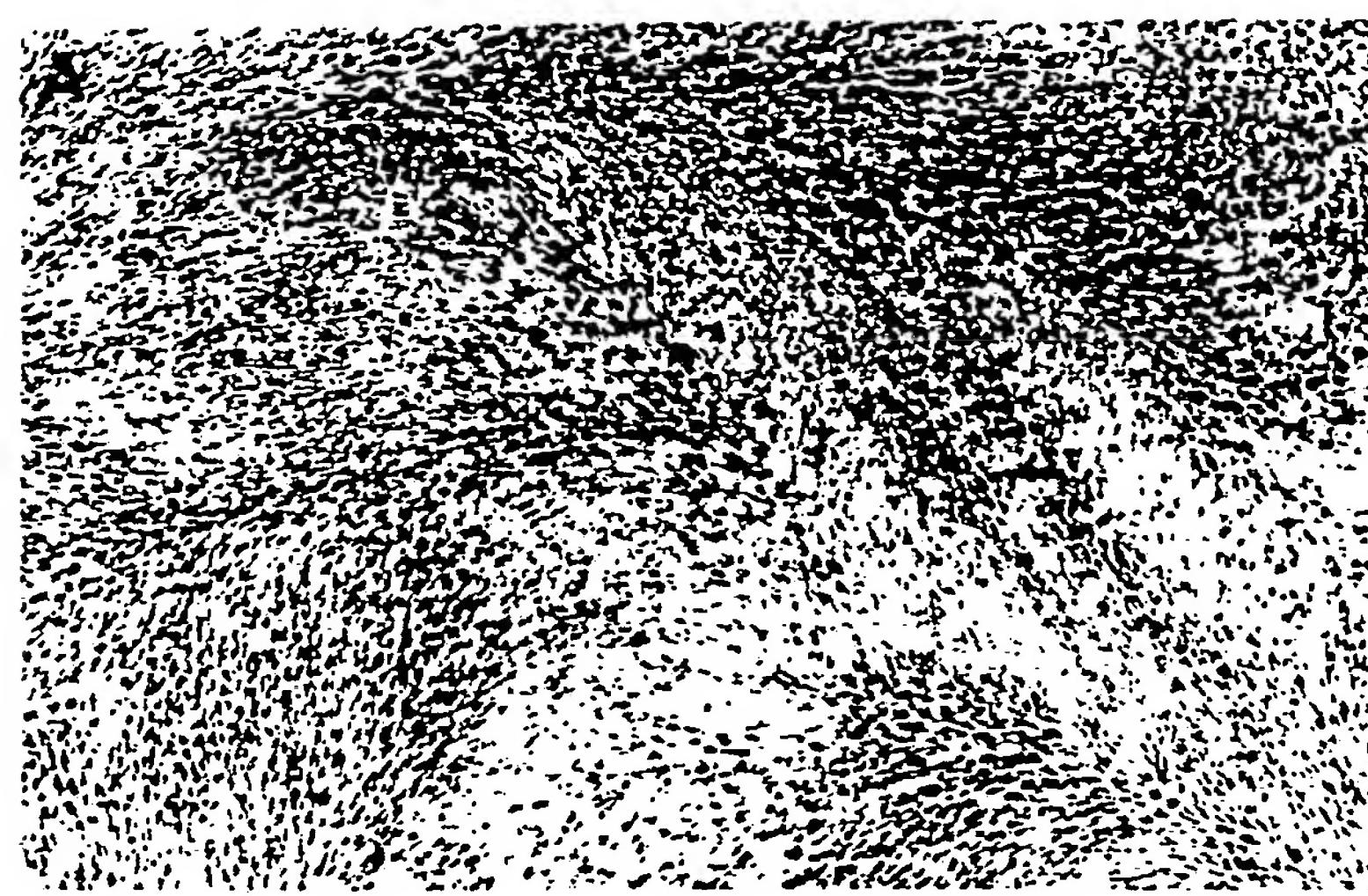
FIG.4
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FIG. 5.

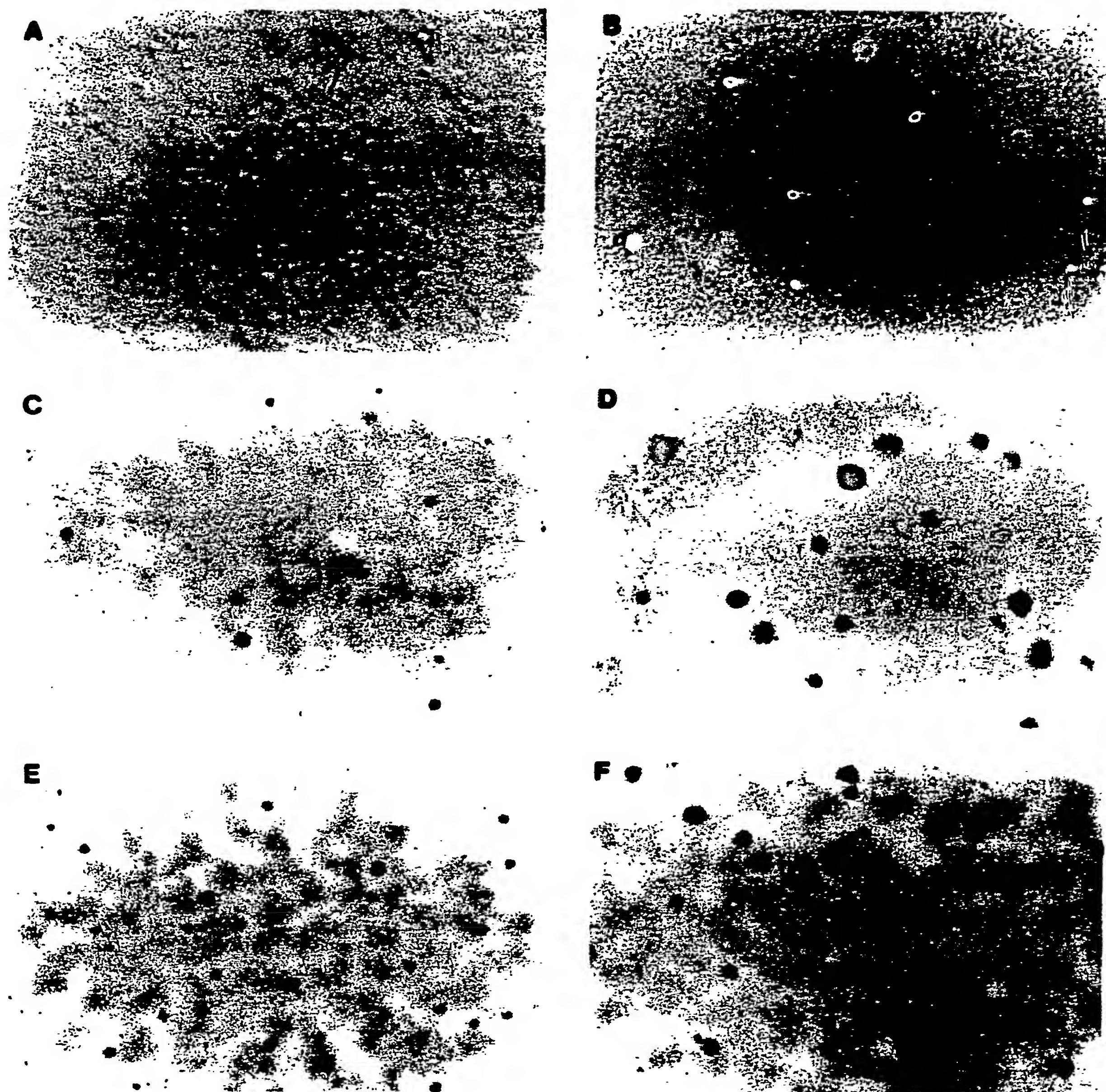


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FIG. 6**SUBSTITUTE SHEET**

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FIG. 7



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INTERNATIONAL SEARCH REPORT

International Application No. PCT/US89/00462

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) ⁶

According to International Patent Classification (IPC) or to both National Classification and IPC

IPC(4) : C12Q 1/02

U.S. C1. : 435/29

II. FIELDS SEARCHED

Minimum Documentation Searched ⁷

Classification System	Classification Symbols
U.S.	435/29

Documentation Searched other than Minimum Documentation
to the Extent that such Documents are Included in the Fields Searched ⁸

III. DOCUMENTS CONSIDERED TO BE RELEVANT ⁹

Category [*]	Citation of Document, ¹¹ with indication, where appropriate, of the relevant passages ¹²	Relevant to Claim No. ¹³
A X	US, A, 4,480,038 (CHENG) 30 October 1984 (see col. 2, lines 32-40 and 60-68)	1-20 and 24 21-23
A	US, A, 4,532,204 (CRESPI) 30 July 1985	

* Special categories of cited documents: ¹⁰

- "A" document defining the general state of the art which is not considered to be of particular relevance
- "E" earlier document but published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

IV. CERTIFICATION

Date of the Actual Completion of the International Search

25 April 1989

International Searching Authority

ISA/US

Date of Mailing of this International Search Report

12 JUL 1989

Signature of Authorized Officer

Sam Rosen
SAM ROSEN

See notes on accompanying sheet